U.S. DEPT. OF AGRICULTURE

Survey report on the Trinity river watershed. Letter from the Secretary of agriculture... 1942

77th Congress, 2d Session - - - - - House Document No. 708

SURVEY REPORT ON THE TRINITY RIVER WATERSHED

LETTER

FROM

THE SECRETARY OF AGRICULTURE

TRANSMITTING

A REPORT OF A SURVEY OF THE TRINITY RIVER WATERSHED IN TEXAS BASED ON AN INVESTIGATION AUTHORIZED BY THE FLOOD CONTROL ACT OF JUNE 22, 1936

APRIL 20, 1942.—Referred to the Committee on Flood Control and ordered to be printed with illustrations

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1942

UNITED STATES DEPARTMENT OF AGRICULTURE

FIELD FLOOD CONTROL COORDINATION COMMITTEE NO. 8

Program for run-off and water-flow retardation and soil-erosion prevention pursuant to Section 6 of the Flood Control Act, June 22, 1936; Public, No. 738, Seventy-fourth Congress; Public, No. 761, Seventy-fifth Congress; and Public, No. 591, Seventy-fifth Congress

II

LETTER OF TRANSMITTAL

DEPARTMENT OF AGRICULTURE,
Washington, April 3, 1942.

Hon. SAM RAYBURN,
Speaker of the House.

DEAR MR. RAYBURN: I am transmitting herewith a report of a survey of the Trinity River watershed in Texas, based on an investigation authorized by the Flood Control Act of June 22, 1936. The report outlines a plan of action for "run-off and water-flow retardation and soil-erosion prevention" in aid of flood control. I have approved the plans contained in this report.

In the estimation of the Department, a watershed-improvement plan for the Trinity River drainage is deserving of high priority among such projects. The survey reveals serious damages from flood, erosion, and sedimentation attributable in a major degree to improper land use. The improvement program recommended is designed to reduce the run-off, erosion, and flood hazards by conversions in land use and installation of remedial measures which will also improve the economic stability of the people on the land.

The total cost of the proposed program is estimated at $58,950,000 for the 15-year period of installation. Of this total installation cost it is estimated that the Federal Government must contribute $32,000,000, State or local governments $125,000, and farmers and other individuals $26,825,000. Of the cost to farmers, $13,784,000 is for materials and labor and $13,148,000 for maintenance and increased farm operating costs.

After the 15-year period of installation the program will cost approximately $1,426,000 annually to maintain. Of this amount the Federal Government must contribute $22,850, the State and local governments $8,100, and local farmers $1,395,000.

The over-all benefits from the program are estimated to amount to $2.88 for each $1 of cost. Annual Federal costs are estimated to return a public benefit of $1.48 for each $1 of cost.

The plan proposed by the Department has been integrated with that of the Corps of Engineers and local agencies with whom the Department has consulted since the initiation of the investigation. There are no power developments involved in this program.

It was originally intended that the recommended programs for watershed improvement would be initiated with funds from the $4,000,000 made available to the Department for such work in Public, 591 (75th Cong.), approved June 11, 1938, in accordance with the authority provided in section 7 of the Flood Control Act of June 28, 1938. However, prior to the initiation of this project the Department was advised of the President's view concerning projects of this nature during the existing world crisis. The President's recommendations were subsequently incorporated in Public Law 228

(77th Cong.), the Flood Control Act of 1941. Accordingly, I am not recommending at this time an allocation of funds from the balance available under Public, 591 (75th Cong.) or under subsequent acts.

Although initiation of the project should be deferred until after the present emergency, the need for the program on this watershed is so great, and the cost-benefit ratio is so favorable, that it is recommended that the report be printed and that Congress provide for carrying out the recommended program so that the project may be ready for initiation when the time is opportune and funds can be made available for its installation.

We have been advised by the Budget Bureau that there is no objection to the submission of the attached report on the Trinity River watershed.

Sincerely,

CLAUDE R. WICKARD, *Secretary.*

LETTERS OF SUBMITTAL

DEPARTMENT OF AGRICULTURE,
Washington, January 13, 1941.

MEMORANDUM FOR THE SECRETARY

DEAR MR. SECRETARY: We are submitting for your approval the attached report which recommends a watershed-improvement program for the upper portion of the Trinity River Basin in Texas. This proposal is based on a detailed survey of this watershed authorized by the Flood Control Act of June 22, 1936, as amended. It is coordinated with the action and research programs of the Department in this watershed, and is in harmony with, and complementary to, the tentative plans of the War Department for flood control and navigation on this stream.

The survey of the Trinity watershed by the Department of Agriculture has been a cooperative undertaking of the Soil Conservation Service, the Forest Service, the Bureau of Agricultural Economics, and the Office of Land Use Coordination. Various Federal, State, and local agencies having an interest in the land and water resources of the watershed have been consulted frequently during the progress of the survey and have given informal expressions of approval of the proposed program.

As you will note from the report, the detailed survey of the Trinity revealed a serious problem of damages from flood, erosion, and sedimentation, in large part arising from improper land use. The improvement program recommended is designed to reduce materially the run-off, erosion, and flood hazards by shifts in land use and installation of remedial measures, which also would improve the economic stability of the people on the land. Average annual costs for the complete program including Federal, State, and individual expenditures, are estimated at approximately $5,478,000 as compared with benefits of about $15,800,000—a ratio of $2.88 in benefits for each $1 of costs. Included in total average annual costs are Federal costs of $966,000, as compared with off-site or purely flood-control benefits of $1,438,000—a ratio of $1.48 in benefits for each $1 in costs.

The primary responsibility for the execution of this program will rest with the Soil Conservation Service working through soil-conservation districts, which have been organized or are in the process of organization over practically all of the watershed. The work will be carried out, of course, in close cooperation with other interested agencies of the Department and with State and local governmental units.

To initiate the program it is recommended that the sum of $1,471,000 be allotted immediately out of the $4,000,000 contained in the War Department Civil Appropriation Act of 1939, approved June 11, 1938,

in accordance with the authority provided in section 7 of the Flood Control Act of June 28, 1938. It is anticipated that work under this allotment would begin on such parts of the following tributaries of the Trinity River as are included in soil-conservation districts, as follows: (*a*) West Fork, above Lake Worth Dam and the Fort Worth-Dallas area, including Red Oak, Mountain, and White Rock Creeks and other short direct drainages into the main stem, and (*b*) Chambers-Richland Creek.

Because of the seriousness of the flood and erosion problem in this watershed, which threaten the livelihood of many farm families and the continued productivity of large areas of land, and in view of the large benefits that would accrue from remedial action, we earnestly recommend your approval of the attached report and its transmittal to the President.

Respectfully submitted.

H. R. Tolley,
Chief, Bureau of Agricultural Economics.
D. S. Myer,
Acting Chief, Soil Conservation Service.
Earle H. Clapp,
Acting Chief, Forest Service.
M. S. Eisenhower,
Land Use Coordinator.

Office of the Chief of Engineers,
Washington, December 17, 1940.

Mr. M. S. Eisenhower,
Land Use Coordinator, Department of Agriculture,
Washington, D. C.

Dear Mr. Eisenhower: Reference is made to your letter of October 31, 1940, with the survey report of the Department of Agriculture, which recommends a program of water-flow retardation and soil-erosion prevention for the Trinity River watershed in Texas.

The report has been reviewed by this Department and my views with respect to the general character of the proposed work and its relation to improvement work being investigated by this Department under authority of the River and Harbor Act approved July 3, 1930; and the Flood Control Act approved June 22, 1936; are herewith.

Your report presents a plan for soil conservation and general land improvement in the watershed of the Trinity River north of Palestine by treatment of cultivated lands, pastures, and woodlands to reduce soil and water losses; by conversion of eroded lands to pasture, meadow, and woodland; by public purchase and treatment of land in critical areas; and by installation of adequate fire control to prevent continued denuding of portions of the watershed. Benefits from the work are evaluated at $15,800,041 per year. Retardation of water-flow as contemplated in the report would have a modifying effect on peak flows of the smaller streams, which would reduce recurrent flood losses in the valleys. Prevention of soil erosion as proposed would reduce sedimentation in reservoirs and channels and lessen the cost of maintenance for such improvements as are under investigation by this Department at the present time for navigation and flood control.

In view of these contingent benefits, which are evaluated in your report at $680,639 per year and included in the total benefits of $15,800,041, the program recommended in your report is considered to be in harmony with and a valuable supplement to the major flood control plan now under investigation by this Department.

Very truly yours,

THOMAS M. ROBINS,
Brigadier General, Corps of Engineers,
Assistant to the Chief of Engineers.

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SURVEY REPORT OF THE TRINITY RIVER WATERSHED

Summary

The Trinity River drains an area of approximately 11,280,000 acres, entirely within the State of Texas. The watershed supports a total population of 950,000 people, and includes two of the largest cities in the State, Dallas and Fort Worth. This report covers in detail only that part of the watershed above Palestine, Tex., and area of approximately 8,260,000 acres.

The watershed has a serious problem of accelerating damages from flood, erosion, and sedimentation, which in large part arise from improper land use. The direct erosion and related damages on uplands of the Trinity are estimated to be $5,589,000 annually. Direct flood damages on the tributaries of the river are estimated to be $1,133,000 annually, exclusive of damages on the flood plain to be protected by proposed Army reservoirs. Of the total flood damage, 86 percent is agricultural, and the rest is damage to public highways, railroads, and urban residential and municipal areas. Damages resulting from sedimentation in reservoirs are estimated to be $140,000 annually.

The plan proposed by the Department of Agriculture as a result of this survey provides for retardation of water flow and prevention of erosion through: (1) Treatment of the cultivated lands, pastures, and woodlands to reduce soil and water losses; (2) conversion of eroded lands to pasture, meadow, and woodland; (3) public purchase and treatment of land in critical areas; and (4) installation of adequate fire control to prevent continued denuding of portions of the watershed.

Recommendations

A program of water-flow retardation and soil-erosion prevention, pursuant to the Flood Control Act of 1936, as amended, is recommended for the Trinity River watershed as follows:

1. That $32,000,000 be authorized under the flood-control act and appropriated and expended under the flood-control and other acts by the Department of Agriculture for the above-mentioned program on the Trinity watershed over a 15-year period.

2. That the sum of $1,471,000 be allocated immediately out of the $4,000,000 already available to the Department of Agriculture for run-off and water-flow retardation and soil-erosion prevention to begin operations on such parts of the following tributaries as are included in soil-conservation districts: (*a*) West Fork, above Lake Worth Dam and the Fort Worth-Dallas area, including Red Oak, Mountain, and White Rock Creeks, and other short, direct drainage into the main stem, and (*b*) Chambers-Richland Creek.

3. That $71,670 of the total of $32,000,000 be spent only on condition that the State of Texas or its governmental subdivisions (1) agree

to cooperate by spending $9,000 for the installation of forest-fire-control facilities in parts of the Gulf Coastal Plain area; and (2) assume obligation to provide approximately $8,100 annually to cover part of the cost of the operation of those facilities.

4. That provision be made to reduce certain expenditures from the $32,000,000 of flood-control funds if future appropriations are used on the watershed under Public, 46, Seventy-fourth Congress, the Soil Conservation Act of 1935, for support of soil-conservation districts; under the Soil Conservation and Domestic Allotment Act of 1936 for encouragement of certain soil-building practices; and under title III of the Farm Tenant Act for acquisition and development of submarginal land; as follows:

A. Amounts expended from future allotments under the Soil Conservation Act of 1935 used in the upper Trinity watershed will be deducted from flood-control expenditures to the extent to which they replace flood-control costs included in the proposed program of water-flow retardation and erosion prevention.

B. Amounts expended in the upper Trinity watershed under the Soil Conservation and Domestic Allotment Act for soil-building practices will be deducted from flood-control expenditures to the extent to which they replace Federal costs included in the proposed water-flow retardation and erosion-prevention program.

C. Of the total sum requested for this program, approximately $4,652,000 represents funds to be expended in accordance with title III of the Bankhead-Jones Farm Tenant Act for acquisition, development, management, and maintenance of between 225,000 and 250,000 acres of submarginal land in the Trinity watershed. An existing purchase project in this watershed had acquired 13,000 acres by February 28, 1940. Future appropriations under title III of the Bankhead-Jones Farm Tenant Act used to extend land purchase in this area will be deducted from expenditures under the flood-control act.

5. That cooperation with farmers to install the program of water-flow retardation and erosion control in the Trinity watershed shall be conditioned on appropriate coordination with the agricultural conservation program in that watershed. Such coordination shall consist of: (1) Recommendation by the State Agricultural Adjustment Administration committee and approval by the Agricultural Adjustment Administration of the use of farm-conservation plans under a provision of the kind outlined in section 1 (k) (5) of the 1941 Agricultural Adjustment Administration program bulletin, under which counties or groups of counties may, on recommendation of the State committee, reduce payments with respect to crop allotments up to 50 percent for failure to carry out soil-building practices specified under a farm conservation plan for the farm; and (2) require that such farm-conservation plans shall be in accord with farm plans used in carrying out remedial measures under the program of water-flow retardation and erosion control. When the plan for water-flow retardation and erosion-prevention is developed for a given farm, the farm-conservation plan shall be in accord with the plan for water-flow retardation and erosion-prevention for such a farm as to types and locations of such measures.

6. That Congress authorize the Department of Agriculture and the War Department to make a joint survey to determine the engineering and economic feasibility of small storage reservoirs for flood control

on the tributaries of the Trinity River watershed. Data obtained by the survey on which this report is based indicate that small flood-control storage reservoirs on the minor tributaries, not affected by the tentative War Department plan, would reduce further the flood damages remaining after the installation of the proposed program of water-flow retardation and erosion prevention. Such small storage reservoirs also would make possible a more complete use of the flood-plain lands. The possible additional benefits which would accrue from such reservoirs justify a joint investigation as recommended.

DISTRIBUTION OF FEDERAL FUNDS

The measures recommended for installation and the amount of Federal funds required for this program are as follows:

1. Farm-land treatment (to be undertaken by farmers under cooperative agreement with soil-conservation districts, the Department of Agriculture supplying technical services and supervision and a portion of the materials, equipment, and labor necessary for application of remedial measures)	$27, 172, 000
2. Public purchase of land	2, 068, 579
3. Treatment of land recommended for public purchase (to be undertaken by the Department of Agriculture and to include development, maintenance, and administration)	2, 583, 475
4. Fire control (to be undertaken by the Department of Agriculture in cooperation with the State of Texas, the Department to supply ⅔ of cost for installation of fire-control facilities and ⅓ of the cost of annual operation and maintenance)	71, 670
Total	31, 895, 724
Total requested	32, 000, 000

This estimate of $32,000,000 maximum total Federal expenditure for the entire program is large enough to cover the necessary contingencies and uncertainties under present conditions.

In addition to these expenditures from Federal funds, State or local governments must contribute approximately $125,000, and farmers and other individuals must expend an estimated $13,784,000 in the form of labor and materials to install the program. Farmers and other individuals also will contribute an additional $13,148,000 in the form of maintenance and increased farm operation costs during the 15-year installation period. The total cost of the program during a 15-year period is thus approximately $58,950,000.

For operations, maintenance, and replacement, after the 15-year period, an average of approximately $1,426,000 will be required annually. Of this, farmers will provide $1,395,000, the Federal Government $22,850, and the State of Texas, or its subdivisions, $8,100.

ECONOMIC JUSTIFICATION

It is estimated that the program will yield the following average annual equivalent benefits:

Prevention of direct flood damage		$598, 221
To crops and pasture	$401, 303	
To agricultural property	111, 455	
To nonagricultural property	85, 463	
Increase in net income from added crop acreage in flood plain		757, 034
Prevention of sedimentation of reservoirs		82, 418
Total flood-control benefits		1, 437, 673

Increase in gross farm income on land treated—conservation benefits	$14, 134, 589
Rental income and gain in yield income froml and purchased and treated	227, 779
Total annual benefits	15, 800, 041

If a plan for large flood-control structures and navigation development should be carried out on the Trinity waterways by the War Department, the value of benefits from the recommended water-flow retardation and erosion-prevention program will be increased measurably. The value of sediment reduction would be trebled, at least, and the reduction of sediment in the navigation system is conservatively estimated as being worth $250,000 annually.[1]

The average annual equivalent costs of the program are approximately $5,478,000, as compared with average annual benefits of $15,800,000 giving $2.88 of benefits for each $1 of cost. Federal costs, on an annual equivalent basis, will be approximately $966,000, as compared with off-site or flood-control benefits of about $1,438,000, giving $1.48 of benefits for each $1 of cost.

Introduction

On March 17, 1938, the Department of Agriculture completed a preliminary examination of the Trinity River watershed in Texas, pursuant to the Flood Control Act of 1936, as amended. This examination disclosed a serious, widespread, and progressive problem of erosion, rainfall run-off, and flooding. It indicated that, despite the many adverse physical, social and economic conditions which would have to be taken into account, a remedial program could check much of the damage, and resulting benefits would greatly exceed the cost of control.

Accordingly, on June 29, 1938, the Department began a detailed investigation of the flood and sediment-producing areas of the Trinity watershed. A small technical staff of soils men, engineers, agronomists, hydrologists, and economists made the survey. This report to the President and the Congress presents the findings and recommendations resulting from this survey.

In making an analysis of the Trinity watershed it was necessary to study erosion and flood problems of each tributary watershed separately. Also, it was necessary to subdivide each physiographic division into appropriate land-use type areas to make determinations for remedial treatment. Types of remedial measures, their costs, and the resulting benefits vary appreciably by land-use type areas.

This report first presents a brief analysis of the physical features and the economy of the entire watershed. This is significant background, because most of the land in the watershed is privately owned, and a considerable proportion is operated by tenants. It is essential to bear in mind that a remedial program will not be adopted merely because engineering designs and vegetative methods are technically sound. Control measures, to succeed, must be in harmony with the economic needs of those who own and those who work the land. Furthermore, the basic resources which will be affected by remedial measures for water-flow retardation and erosion prevention are used by these people for their livelihood. It follows that the public generally cannot rea-

[1] Estimate from a report by Gen. Herbert Deakyne to the Trinity River Canal Association, May 15, 1937.

lize flood-control benefits from improved-land use without the cooperation of the land users and without affecting their welfare. Therefore an economical, feasible remedial program in the Trinity watershed is one which will yield great benefits to the people on the land as well as to the people downstream. In this watershed the downstream benefits alone exceed the public cost. However, separate computations of this sort are somewhat misleading because the public benefits downstream can be obtained only by measures which yield on-site benefits many times larger than those downstream.

The second section of the report presents the findings of the survey as to the specific damages from erosion, sedimentation, and flood which are occurring in the Trinity Basin. The nature, extent, and progress of the damage first is summarized for the watershed as a whole, and then is detailed by watershed problem areas.

The third section reviews the activities of public agencies now operating in the watershed which have a direct or incidental bearing on the problem of flood control and erosion prevention.

The fourth section presents the remedial program recommended by the Department in the light of the existing flood and erosion problem, the use of the land, and the existing economy of the watershed. Each remedial measure is discussed in detail as to the type of land to which it would be applied and manner of application. The methods of accomplishing the remedial program are developed on the basis of that part of the work to be performed by farmers, and that part to be handled by public agencies, including plans of operation through soil-conservation districts, and coordination with the programs of other agencies which affect land use.

An appraisal of the expected benefits of the remedial program is given in the fifth section. Development of costs of the program and a comparison of costs and benefits close the report.

The watershed-improvement program presented in this report has been correlated with the plan of flood control being developed for the Trinity River by the War Department. The program has taken into account the probable locations of any flood-control structures which may be built by the War Department, and no benefits are claimed for the remedial program of the Department of Agriculture on flood plains which would be controlled by such structures. Therefore, this document represents the Department of Agriculture's contribution to a coordinated attack on the flood and erosion problems of the Trinity Basin.

Section I. Description of the Watershed

PHYSICAL FEATURES

Location and size.—The Trinity River watershed, comprising a total of 11,286,000 acres, lies wholly within the eastern half of Texas. The river, as shown in figure 1, rises in the north-central part of the State south of the Red River Basin, flows in a southeasterly direction through the cities of Fort Worth and Dallas, and enters the Gulf of Mexico through Galveston Bay.

The river flows successively through seven distinct physiographic divisions: (1) West Cross Timbers, (2) Grand Prairie, (3) East Cross Timbers, (4) Blackland Prairie, (5) Gulf Coastal Plain, (6) Coastal

Flatwoods, and (7) Coast Prairie. The flood plain constitutes an eighth division.[2]

Climate.—Average annual rainfall varies from less than 30 inches in the northwest extremity of the watershed to 50 inches in the Gulf area.[3] Rainfall is generally well distributed throughout the year and is usually sufficient for growing crops. Severe droughts are experienced at 8- to 10-year intervals in parts of the watershed, causing serious deterioration in the normal protective vegetation. The growing season varies from 200 days in the headwaters to 300 near the mouth. The ground seldom freezes and when it does, freezing is shallow.

The Trinity watershed is subject to severe storms from both the Gulf of Mexico and the Pacific Ocean, which may cause floods. Tropical hurricanes and thunderstorms originating in the Gulf and moving northward across the lower Trinity cause the most frequent floods. Storms moving from the Pacific are not so intense nor frequent but may cause large general floods, since they travel down the major axis of the watershed, covering a larger area.

Geology, topography, soils, and ground water.—The watershed is underlain by inclined layers of sedimentary sand, sandstone, shale, clay, limestone, and marl. Outcroppings of these strata form a series of smoothly sloping plains with escarpments facing the northeast and becoming more prominent toward western headwaters. Where the outcrops are sands, clays, or sandstones the topography is gently rolling with broad, low-gradient valleys between smooth, timbered uplands. Where limestone outcrops, the topography is rougher, broken by ledges, and the stream valleys are narrow, with steeper gradient. Typical uplands are smooth to rolling prairies.

The sandy strata are the source of much artesian or underground water, and the Trinity sands of the West Cross Timbers and the Woodbine sands of the East Cross Timbers are important acquifers on which well supplies of water depend. The need for ground-water supplies has increased in recent years, yet severe erosion and intense cultivation of the land have lowered the efficiency of the catchment basin.

Dark clay-textured fertile soils have developed from limestone and marl formations, as in the Grand Prairie and Blackland Prairie. They absorb surprisingly large amounts of moisture during short rains, particularly after dry periods. However, during storms of flood-producing intensity and duration these soils swell and become relatively impervious, and a rapid run-off of water results.

In contrast, the soils evolved from sandstone and sandy clays have a low fertility and a loose sandy topsoil. They will not stand continuous cultivation without use of fertilizers or additions of organic matter. They absorb moisture more readily than the clay soils, but intense rains soon exceed their moisture-holding capacity, and damaging run-off occurs, particularly in cultivated or eroded areas.

Vegetation.—Before its settlement, the Trinity Basin was dominated by tall grasses, big and little Bluestem, Indian grass, and Texas needlegrass. Even in the woodland they made an almost continuous water-retarding, soil-holding cover. The wooded areas of the East and West Cross Timbers probably were held to a clean-boled open

[2] Detailed descriptions and maps of each physiographic division are given in appendix A.
[3] See appendix B for complete discussion of rainfall, and appendix A, map A–4 showing annual rainfall.

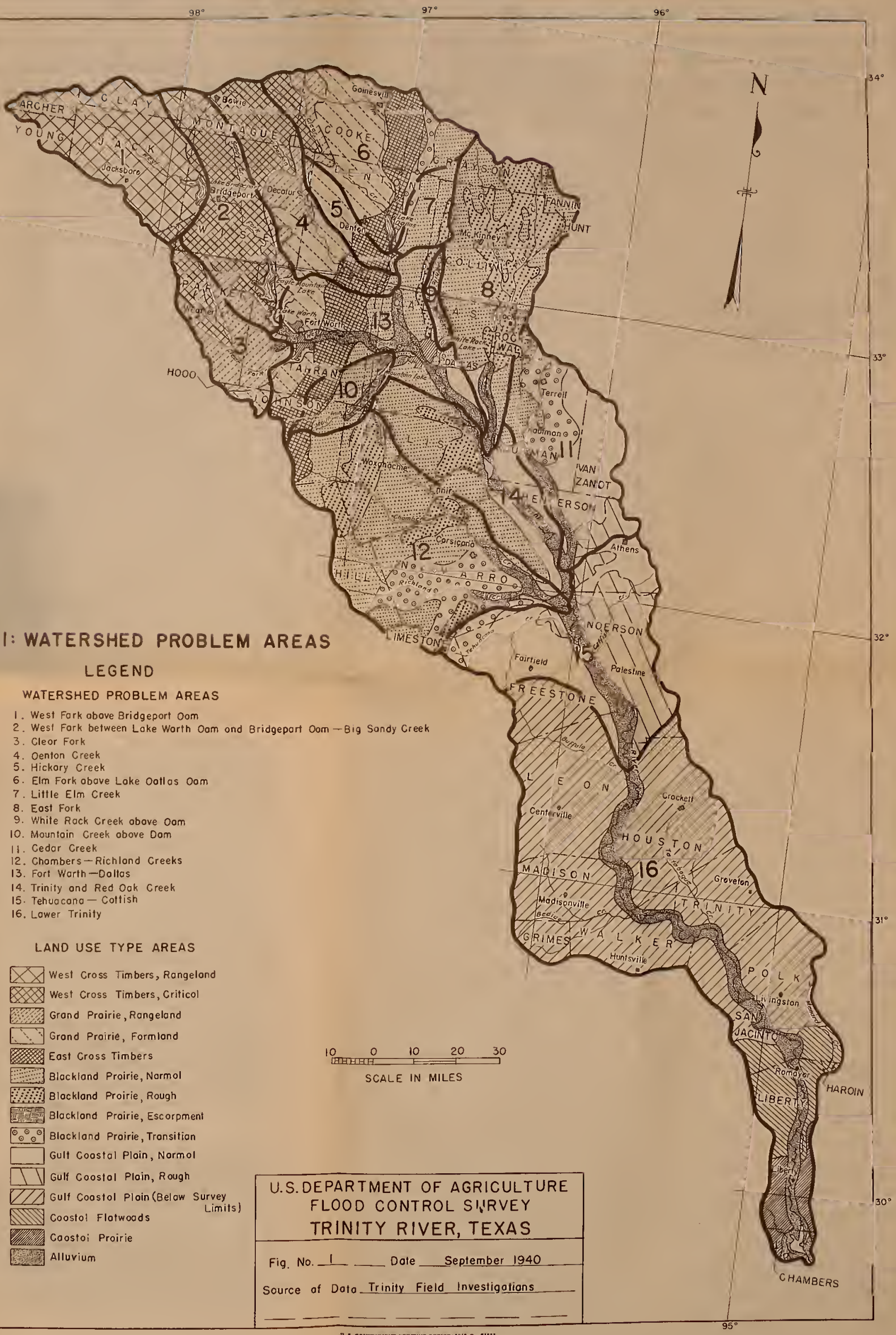

FIG. 1: WATERSHED PROBLEM AREAS

LEGEND

WATERSHED PROBLEM AREAS

1. West Fork above Bridgeport Dam
2. West Fork between Lake Worth Dam and Bridgeport Dam — Big Sandy Creek
3. Clear Fork
4. Denton Creek
5. Hickory Creek
6. Elm Fork above Lake Dallas Dam
7. Little Elm Creek
8. East Fork
9. White Rock Creek above Dam
10. Mountain Creek above Dam
11. Cedar Creek
12. Chambers — Richland Creeks
13. Fort Worth — Dallas
14. Trinity and Red Oak Creek
15. Tehuacana — Cottish
16. Lower Trinity

LAND USE TYPE AREAS

- West Cross Timbers, Rangeland
- West Cross Timbers, Criticol
- Grand Prairie, Rangeland
- Grand Prairie, Farmland
- East Cross Timbers
- Blackland Prairie, Normal
- Blackland Prairie, Rough
- Blackland Prairie, Escorpment
- Blackland Prairie, Transition
- Gulf Coastal Plain, Normal
- Gulf Coastal Plain, Rough
- Gulf Coastal Plain (Below Survey Limits)
- Coastal Flatwoods
- Coastal Prairie
- Alluvium

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
TRINITY RIVER, TEXAS

Fig. No. 1 Date September 1940

Source of Data Trinity Field Investigations

(Faces p. 6)

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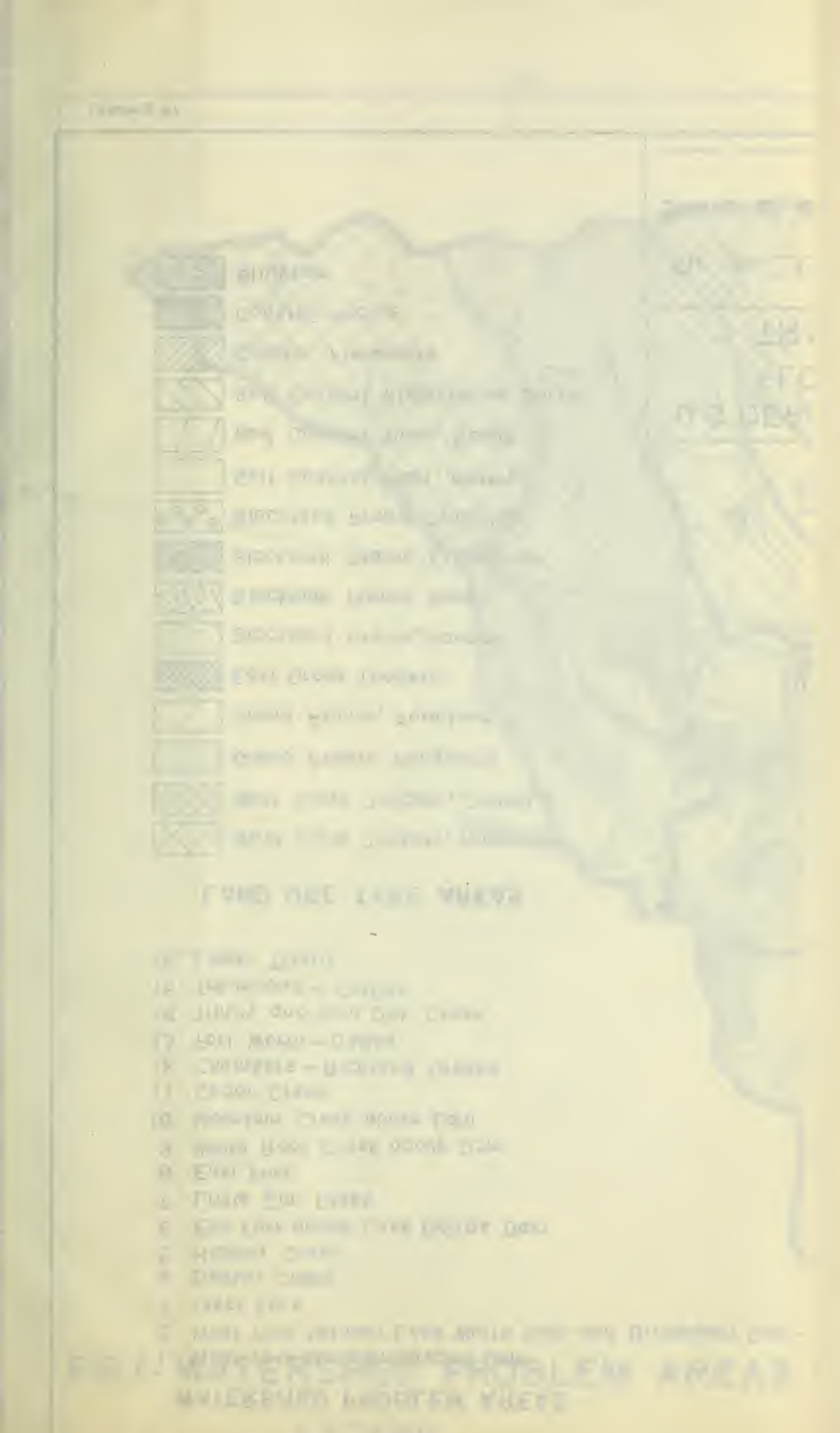

stand. On the lower part of the watershed, from the Gulf Coastal Plain to the Coast Prairie, forest was dominant, standing over a floor of litter which was capable of absorbing a large portion of the rain that normally fell. The dominance of the grasses and the woods has almost completely given way under present land use. Only 46 percent of the land remains in grass, pasture, or woods. A high intensity of grazing has caused the tall perennial grasses to be replaced by annual weeds, annual grasses, and scrubby woody vegetation. Timber stands are 60 percent of former density. The litter layer under the timber, formerly 2 to 6 inches deep, is almost gone.

Crops.—A wide variety of crops are adapted to the watershed. Cotton is the principal cash crop, except in the western fourth of the basin, where small grains furnish cash income. Corn is grown for feed, usually on poor-yielding, sandy soils but is a cash crop in some areas where yields are high. Sorghums, such as hegari, kaffir, milo, and red top cane are produced for both feed and grain, and cane is harvested and baled for hay, particularly in the Blackland Prairie. Cash-grain production is confined largely to the prairie sections, but oats are becoming more prominent as a hay or feed crop in the sandy areas. Other hay crops are sudan, vetch, peas, or peanuts in the sandy lands, and alfalfa and sweetclover in the prairies. In some sections special crops such as onions in the Blackland Prairie and peanuts, small fruits, and melons in the East and West Cross Timbers are becoming more important.

Because of the numerous crops adapted to the watershed, diversification of crops and sources of crop income is possible and desirable. A well-planned sequence of crops tends to maintain fertility and to offer partial protection from damaging erosion and run-off. Disease, drought, and low prices are less liable to cause severe losses when the cropping plan provides for the systematic use of several crops. A simple rotation adapted to the prairie section is cotton, followed by corn or sorghums, small grains, and then sweetclover for 2 years. The sandy section has less selection. However, cotton can be followed by corn, or peas grown for hay, with a winter cover of vetch or Austrian peas.

ECONOMY OF THE WATERSHED

Development.—A ranch economy came with the early Spanish settlement of the Coastal Prairies and generally preceded crop production on the Trinity River. Agricultural development was confined largely to the sandy wooded areas until after the middle of the nineteenth century, when the introduction of a satisfactory sod plow and the building of railroads stimulated breaking the open prairie for crop production.

In the eastern two-thirds of the watershed, settlers came from the Southeast, bringing the single-crop cotton economy of the Old South. This single-crop system continues to prevail in this area with minor modifications. In the western third of the watershed ranching still predominates, except for the cultivation of some of the better soils of the West Cross Timbers area.

Today 87.5 percent of the watershed area is in farms, 4 percent in timber holdings, and 8.5 percent in towns, roads, rivers, and waste-

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land. Crop production utilizes 44.7 percent of the land, and 42.8 percent is in pasture, range, or farm woodlands.

Population.—The total population of the watershed is 950,000, an average of 76 per square mile, as compared with 22 for the State as a whole and 42 for the United States. Forty-four percent of the people live in the cities of Fort Worth and Dallas, 26 percent in small towns, and 30 percent on farms. The farm population averages 22 per square mile, as compared with 9 for the State and 10 for the United States.

Types of farms.—Although the type and size of farms vary significantly from one land use area to another, the present pattern of farms in the watershed is largely made up of—

(1) Row-crop farms, least capable of retarding water run-off and erosion, comprising 40 percent of the farm area and 60 percent of the total number of farms. They range in size from small subsistence units in the sandy-land areas to the large mechanized cotton farms of the Blackland Prairie.

(2) General farms, on which row-crop acreage is balanced with close-growing crops or pasture. These farms take up about 20 percent of the area and are particularly important in the Grand Prairie division, where small-grain production is the chief source of farm income.

(3) Pasture farms, which comprise about 12 percent of the farm area, are relatively resistant to run-off and erosion because of the high proportion of permanent pasture and timber.

(4) Ranches, which are most resistant to run-off and erosion because of their permanent cover and relatively small acreages of cultivated crops, occupy about 12 percent of the farm-land area. Ranches and pasture farms take up three-fourths of the farm land in the West Cross Timbers and Grand Prairie range-land areas.

Size of farms and income.—Many farms are too small to support their operators without exploiting the land. The average farmer in the Trinity Valley has insufficient income to finance improvements necessary for protection of the land. Nevertheless erosion must be checked on these farms; otherwise its present rate soon will reduce all bases of livelihood. The average farm is approximately 180 acres in size, and the average annual net return, with no allowance for interest charges on land and equipment, is approximately $750. In the less productive, sandy, wooded areas the average annual farm income for typical farms ranges from less than $200 for "crop farms abandoned" in the West Cross Timbers [4] to more than $2,700 for large ranches in the Grand Prairie. The average is approximately $450. In the more fertile prairie divisions the average farm income is about $960 a year, ranging from less than $300 for woodland-pasture farms to over $3,450 for large ranches.

Farm tenancy.—Tenancy increased from 35 percent of the total operators in 1880 to 60 percent in 1935 and varies from 70 percent in the intensively cultivated Blackland Prairie, transition area, to a low of 43 percent in the West Cross Timbers range lands. The nature of tenancy in this watershed will add to difficulties in bringing about the desired adjustments in land use under the remedial program. Over 80 percent of the land-rental agreements are verbal and indefinite,

[4] Farms now operated but characterized by heavy abandonment of previously cultivated land.

and are based on a cash-crop farming system which emphasizes soil-depleting and erosion-permitting crops. Tenure is very unstable, with approximately 50 percent of all tenants moving from one farm to another each year.

Farm credit.—The common practice of mortgaging each crop at from 8 to 10 percent interest, for an average period of 7 months, has encouraged farmers to concentrate on a cropping system that prevents long-range plans for land improvements.

Local government and finance.[5]—A study of local governments and finances in the watershed reveals multiple taxing authorities, and inequitable assessment system, a heavy debt and tax burden, and excessive tax delinquency. Conditions are such that large contributions from State and local governments cannot be expected in planning for watershed improvement.

There are 10 different types of local agencies in the watershed authorized to issue bonds and levy taxes in addition to the State and Federal Governments (*40*) (*41*).

The general property tax is the chief source of revenue for the State and local governments and has resulted in a serious drain on farmers' income. In 1938 all units of government collected approximately $26,000,000, or $24.50 per capita, in taxes in the watershed.

The assessed valuation of all property in the watershed in 1938 was approximately $701,000,000, of which 60 percent was in Fort Worth and Dallas. It is generally recognized that inequalities in assessment further aggravates an already complicated problem.

The total net public indebtedness (*36*) (*38*), excluding the State debt, in 1938 was approximately $138,000,000, about 20 percent of the assessed valuation. The assessed valuation of all property in the watershed declined 12 percent from 1929 to 1938, as compared with a decline of 2 percent for the State as a whole.

Total tax delinquency from 1919 to 1930 (*40*) was approximately $26,000,000, or equal to 1 year's tax levy. The existing laws concerning tax delinquency, foreclosure proceeding (*39*), tax sales, and tax titles are vague and ineffective.

LAND-USE TYPE AREAS

In studying the problems and developing a remedial program for the Trinity watershed, it was necessary to subdivide each physiographic area, listed on page 8, into various land use type areas on the basis of physical conditions such as soil character, topography, and incidence of erosion.[6] Within each land use type area the farms are generally similar in type, and uniformity is found in soils, land-use capabilities, and run-off and erosion problems. Measures for water-flow retardation and erosion-prevention are somewhat similar within each area.[7]

The break-down of the physiographic divisions by land-use type areas and the acreage in each are shown in figure 2. A brief description of each land-use type area follows:

The West Cross Timbers, an area of sandy soils underlain by impervious clay subsoils is divided into two land-use type areas.

[5] All data cited under this heading are from annual reports of the Texas State auditor and efficiency expert.

[6] Detailed descriptions and maps of each physiographic area are given in appendix A.

[7] Fig. 1 shows land-use type areas within watershed.

NOTE.—Italic figures denote bibliography.

1. The western or range-land portion is a wooded ridge country with valleys of grassland often heavily covered with mesquite brush. Stock ranching is the chief type of farming and erosion is not yet a very serious problem.

2. In contrast, the critical portion is the major erosion problem and source of sediment in the entire Trinity watershed. The original cover of scrub oak, interspersed with grass, has been cleared at one time or another, and at the present the area is occupied by small, severely eroded, cultivated farms. Much land has been abandoned and has reverted to scrub oak.

FIG. 2.—*Land use type areas in the Trinity River watershed*

SURVEYED PORTION

Physiographic division	Land use type area	Acres	
1. West Cross Timbers	(a) Range land	669, 541	
	(b) Critical	789, 242	
			1, 458, 783
2. Grand Prairie	(a) Range land	537, 998	
	(b) Farm land	672, 568	
			1, 210, 566
3. East Cross Timbers			550, 327
4. Blackland Prairie	(a) Normal	2, 120, 112	
	(b) Rough	677, 511	
	(c) Transition	556, 960	
	(d) Escarpment	20, 950	
			3, 375, 533
5. Gulf Coastal Plain	(a) Normal	924, 804	
	(b) Rough	419, 735	
			1, 344, 539
6. Flood Plain			326, 715
Total			8, 266, 463

UNSURVEYED PORTION

1. Gulf Coastal Plain	(a) Normal	958, 373	
	(b) Smooth	1, 112, 845	
	(c) Rough	307, 327	
			2, 378, 545
2. Coastal Flatwoods			260, 451
3. Coast Prairie			125, 762
4. Flood Plain			255, 179
Total			3, 019, 937
Grand total, Trinity watershed			11, 286, 400

The Grand Prairie, an area of dark-clay soils, is subdivided into two areas, one of which is used predominantly for grazing and the other for farming.

1. The range-land portion in the western part of the area is characterized by rolling, shallow topsoil and remains in large part in grass cover, which is used for livestock production. The present grass cover is the remnant of the original prairie vegetation.

2. The farm-land area, one of the very productive portions of the watershed, is occupied by relatively fertile, deep soils and is used for the production of cultivated crops. Its topography is much less rolling than that of the range land. Erosion and run-off occur at rates which have already seriously damaged the land, although destruction of fertility has not progressed to the extent it has in other areas.

The East Cross Timbers, a narrow belt of rolling sandy soils, is sufficiently uniform not to require subdivision. The original vegeta-

tion was scrub oak, with tall grasses occupying open areas. This rather narrow belt across the watershed is now occupied by small subsistence farms on which clean-tilled crops are usually grown. The topography is rolling, and erosion is rather serious on most cultivated fields and in grazed woodlands.

The variety of conditions in the Blackland Prairie requires four land use type subdivisions.

1. The normal area has heavy, granular, clay soils which are deep and productive. Erosion and run-off rates are relatively high, but deep soils and smooth topography tend to obscure the problem. Clean-tilled crops occupy most of this cultivated prairie country.

2. The rough portion occurs chiefly along drainage ways and comprises rolling country where soils are shallower and erosion more apparent. A greater percentage of this land is used for pasture.

3. The transition area occurs between the typical conditions of the Blackland Prairie and the Gulf Coastal Plain. It represents a mixture of the sandy and heavy clay types of soils and the farming of both these areas. Erosion and run-off problems generally are similar to those of the normal area.

4. The escarpment area is a steep, rough outcropping of Austin chalk facing toward the west. Soils are very shallow, and this small area is chiefly devoted to ranches. Because of the topography and the overgrazed condition of the pastures, erosion and run-off problems are serious.

The Gulf Coastal Plain is subdivided into two land-use type areas on the basis of general topography.

1. The normal area is a rolling sandy plain, heavily timbered. Small subsistence-type farms are scattered through it and, while erosion and run-off are locally severe, they do not cause as much damage as in less wooded areas. Grazing livestock and burning off forested lands have seriously injured the protective woodland cover. Below Palestine the timber cover changes from the post-oak type to the shortleaf pine-hardwood, a more valuable type.

2. The rough area is heavily wooded and steeply rolling, with a loose sandy soil that is inherently low in fertility, and a stony or gravelly connected subsoil. Timber consists of post oak, blackjack oak, and hickory. The land is largely devoted to forest or woodland use, although flat-ridge tops and small level fields are cultivated. Many fields have eroded severely and have been abandoned. Erosion is proceeding at a high rate, where the land is not protected by forest cover.

The coastal flatwoods area is a level to gently rolling sandy plain forested in shortleaf and loblolly pine. Owing to impeded drainage, the gray sandy soils are not well suited to crops, and the area is devoted to woodland grazing and timber production. Erosion and run-off are slight.

The Coast Prairie is a level, fertile plain of dark-colored soils, which are utilized for cultivation and grazing. The prairie cover of coarse grass and brush with scattered clumps of trees is well suited to grazing. Some areas are peculiarly adapted to rice production on account of impervious subsoils. Erosion and run-off problems are unimportant.

The alluvium of main flood plain is made up of very fertile, dark, heavy clay soil which resembles the Blackland Prairie soils. Crop

yields are exceptionally high in favorable years and, even with present flood hazards, many farms are located on the plain. Much land is cultivated above the Corsicana but the amount gradually lessens downstream. There are only scattered farms below Palestine. The greater part of the uncultivated land below Corsicana is in forest.

Section II. Erosion- and Flood-Damage Problems on the Trinity Watershed

EROSION DAMAGE

The broad and intense attack of erosion on much of the land on the Trinity watershed has brought about a progressive deterioration of agricultural resources. Evidence of this damage is offered by ruined fields, reduced crop yields, diminishing land values, and damage to roads and highways. Deposits of sand and other erosion debris have destroyed the value of some flood-plain lands, reduced the value of others, and choked stream channels, thus increasing flood frequency and damage.

Losses largely preventable.—The most significant fact revealed by the erosion survey of this watershed is that the tremendous and increasing loss of soil and the rapid run-off of water are largely avoidable by proper land use. Where soil-conserving methods have been followed, topsoil losses have been reduced to a fraction of those on similar but unprotected lands.

In all sections of the watershed, farming has been attempted on some steep, highly erodible slopes. Clearing and planting of these slopes started a destructive erosion, leading to the abandonment of these lands in a few years. A majority of farmers cultivate their fields up and down the slope, causing twice as much sheet erosion and run-off as on contour-cultivated fields (*1*), (*2*), (*5*), (*7*).

Forty-four percent of the watershed is cultivated, and the cultivated land contributes relatively greater amounts of run-off and soil loss than grassland or woodland. Present land use has altered materially the natural balance that existed in presettlement time and is the major cause of the present excessive run-off and erosion.

The prevalent system of continuous cultivation of shallow-rooted, widely spaced crops has lowered fertility and reduced organic content of overtilled and eroded soils to a point where they offer little resistance to erosion and a minimum of opportunity for infiltration of rainfall. Only an occasional farmer in the watershed follows any type of crop rotation, other than changes from cotton to corn. This steady cropping has reduced fertility to such an extent that the vegetative growth of the crop itself is seriously reduced, leaving the soil even more vulnerable to excessive rainfall.[8]

Pasture and range land reduced.—The amount of pasture and range land has been reduced far below that needed for adequate watershed protection and sustained use. Much of the pasture and range is in poor condition. An estimated 400,000 acres of land now used as pasture once were cultivated and then abandoned. Overgrazing has been the greatest factor responsible for excessive run-off and erosion from pastured areas. The density of the vegetation on practically all of the pastured acreage is far below that necessary to prevent erosion.

[8] See appendix E for decline in crop yields.

Production of wood and forage on the same area is incompatible with proper management in all parts of this watershed. Yet more than 1,000,000 acres of pastured range support an overstory of trees or other woody growth.

Woodlands less protective.—Soil and flood protection offered by woodlands in the watershed has diminished greatly.[9] Overgrazing, burning, and indiscriminate cutting have destroyed rainfall-absorbing litter and humus layers, reduced the protection foliage and root volume, and have packed the exposed soil. Practically no virgin or old-growth stands remain in the upper watershed. Cutting has reduced the normal tree cover as much as 50 percent. Seventy-five percent of the woodland has been burned over within the past 9 years.

Experiments indicate that annual burning in stands typical of the Gulf Coastal Plain increases soil losses and water loses 5½ times; and in stands comparable to the West Cross Timbers burning increases water losses 27 times and soil losses 12 times.

Roadside erosion.—Roadside erosion has contributed excessively to the silt load of the many tributaries. The practice of road maintenance has been to clear and deepen the ditches regularly, removing all vegetation. This has resulted in deep gullies and sunken roadbeds from which large quantities of soil wash to clog stream channels below.

Roadside losses are greatest within the West Cross Timbers area where about 7 acre-feet of soil per mile of road have been removed. Since the beginning of the present road system more than 50,000 acre-feet have been washed from the roads and road-drainage ditches of the watershed. This loss, probably averaging 2,000 acre-feet annually, can easily be reduced to small amounts through more careful maintenance of the roadbed.

Extent of soil loss.—Nearly all of the uplands are eroded. Since the beginning of cultivation, 50 to 75 years ago, approximately 1,900,000 acre-feet of soil (fig. 3) have been lost, equal to 2.7 inches of topsoil.

Soil losses vary considerably with different land uses and cover conditions. The highest average yearly soil loss in the Trinity Basin is 29 tons per acre in the eastern cultivated part of the West Cross Timbers. Yet the lowest rate, 7 tons per acre, occurs in the western part of this same area, which still is devoted to range.[10]

FIG. 3.—*Soil loss by land-use-type areas, Trinity River watershed*

Land-use-type area	Total loss to date	Present rate of loss per acre per year
	Acre-feet	*Tons*
West Cross Timbers:		
Range land	54,860	7
Critical	424,632	29
Grand Prairie:		
Range land	88,287	9
Farm land	121,011	12
East Cross Timbers	164,071	16
Blackland Prairie:		
Normal	539,450	10
Rough	180,204	15
Escarpment	3,183	15
Transition	101,899	14
Gulf Coastal Plain:		
Normal	158,099	13
Rough	65,527	12
Total	1,901,223	

[9] See appendix G for relative depths of litter and humus.
[10] See appendix C for methods of calculating soil losses.

Farm income reduced.—A continued progressive decline in yields from field crops, pasture, and woodland can be expected as a result of water run-off, erosion, and other causes. This progressive decline in the net farm income of the watershed is estimated at the rate of $430,000 annually.[11] It is one of the greatest losses associated with the flood and erosion problems of the watershed. One-half of this decline in yields probably can be attributed to a loss of productivity resulting from erosion. Unless a remedial program is adopted, the loss will continue until the land is abandoned.

Lowering of groundwater level.—It is impossible to measure accurately the effect of erosion on lowering the groundwater level, but it is significant that the lowering of the water table since settlement has made it necessary for approximately 2,000 wells to be deepened or replaced.[12] Studies throughout the watershed show that the removal of part of the topsoil materially reduces the rate of infiltration.

SEDIMENTATION DAMAGE

As the process of erosion has accelerated on the uplands of the Trinity watershed, the main stream and its tributaries have carried an increased load of silt and eroded materials, causing damage to flood-plain lands, rapid sedimentation of reservoirs, and increased expense in treating water for domestic and industrial use.

However, all soil eroded from fields is not discharged immediately into the streams and reservoirs. A part, particularly the coarser particles, lodges in the originating or adjoining fields, collects in minor drainage channels, and often is deposited at the edges of alluvial valleys. This delayed movement accounts for difference in total volume of soil eroded in the watershed and the volume measured as deposited in reservoirs, valleys, and Galveston Bay.

The blocking of tributary drainage ways by eroded material prepares the way for heavy damage to valley lands and reservoirs during major floods and also increases the frequency of minor floods.

Plugged channels have increased flood heights above previous levels. The Big Brushey Creek, an extreme example, is plugged with silt in a reach of 20 miles and, as a result, the entire creek valley flood plain of 12,800 acres probably has lost half of its value because of increased flooding.

During major floods the sediment-restricted channels build up high velocity, which moves large loads of coarse material downstream and onto bottomland fields. It is estimated that 116,900 acres of valuable flood-plain lands have been thus damaged. Deposits of sand or gravel on bottomland fields have ruined much of the once fertile alluvial silt loams of the West Cross Timbers, and have spread on alluvial valleys for some distance downstream. A total of 250 miles of valleys in the lower Gulf Coastal Plain alone have been damaged by coarse sediment.[13]

Damages of reservoirs.—Of 21 reservoirs in the Trinity watershed 2 have been filled with sediment, and the remaining 19 are being damaged to the extent of $140,000 annually through loss in storage capacity, reduction in their useful life, increased replacement cost, and increased cost of maintenance.[13]

[11] Methods used in predicting probable declines in yield and income are given in appendix E.
[12] See appendix B.
[13] See appendix D for details on sedimentation damage.

Storage in the remaining reservoirs has been depleted at yearly rates varying from 0.1 to 9.4 percent of reservoir capacity, and sedimentation will increase unless erosion is controlled. In addition to this loss in utility is the social and property loss which accompanies the deterioration of their recreational and scenic value.

It is estimated that deposition in reservoirs is taking place at rates as shown in figure 4 for the various physiographic divisions. It should be emphasized that land use and ratio of reservoir capacity to watershed area are more important factors in determining sedimentation rates than are inherent physical characteristics of physiographic divisions.

FIG. 4. *Estimated rates of sedimentation, Trinity River watershed*

Area:	*Acre-feet annually per 100 square miles of drainage area*
West Cross Timbers:	
Rangeland	75
Critical	275
Grand Prairie	100
East Cross Timbers	150
Blackland Prairie	180
Gulf Coastal Plain	75

Sixteen of the existing reservoirs are used for water supply, and the damage to them from sedimentation is estimated at $61,000 annually.[14] Three additional reservoirs—White Rock, Bachman, and Lake Worth—cannot be replaced in equally desirable locations and, because of their high residential and recreational values, it is anticipated they will be maintained by dredging. The annual equivalent of the expenditures necessary to maintain minimum capacity of these three reservoirs through dredging is approximately $76,000.

Reservoirs of relatively small capacity will become less effective as settling basins, and the water turbidity will gradually increase as the capacity of the reservoir decreases. This will increase water purification cost on 10 reservoirs. This damage in terms of average annual equivalent over the remaining lives of the reservoirs is $1,400.

The damage to reservoirs from sedimentation is calculated only on their continued use for municipal and industrial water supplies. However, four of the reservoirs—Bridgeport, Eagle Mountain, Dallas, and Mountain Creek—are large enough to play an important part in flood control and canalization. At present these lakes have capacity in excess of water-supply requirements which is valuable for flood control. Depletion at present rates will not endanger the water supply for years to come, but will impair multiple use of the reservoirs.

However, should the Trinity be canalized for navigation, all present excess capacity of these four lakes would be needed to provide an adequate, regulated flow and, consequently, would become much more valuable. In this event the monetary loss from the damage at the current rate of sedimentation would become much higher than is estimated at present.

Other sedimentation damage.—Not all the eroded material carried by floodwaters is deposited in stream drainage ways and reservoirs. Much of it remains in suspension to be carried down the entire length of the river and deposited in Galveston Bay. The volume of the bay decreased from 79,500,000,000 cubic feet in 1898 to 71,600,000,000

[14] This figure is the annual equivalent of the amount required to replace the remaining capacity of the reservoirs at the end of their present usual life.

cubic feet in 1937, a net loss of 9.9 percent.[15] This deposition has required continuous dredging in ship channels and at other points in order to maintain navigation.

Approximately 22,000 acres of once valuable muskrat range near the mouth of the Trinity has been so altered by floods and silt that all but a few of these animals have been driven out or starved. In 1938 only 3,000 rats were trapped from the entire area of 22,000 acres; while a nearby ranch, with between 7,000 and 8,000 acres of marsh, produced 60,000 pelts.

The lower Trinity at one time was a very important winter headquarters for wild ducks, geese, and other migratory birds. Silt has nearly filled the lakes and destroyed food supplies.

It should be noted that the damages to the lower Trinity and Galveston Bay from sedimentation would be materially reduced in the event flood-control and storage structures are constructed upstream by the War Department. No benefits are claimed for the Department of Agriculture remedial program in the lower Trinity and Galveston Bay.

FLOOD DAMAGE

The quiet, clear, year-round streams of the presettlement era depended on a continuous blanket of natural vegetation. There is evidence that floods occurred on the Trinity before settlement, but these were vastly different from the present floods. Water rose and receded so slowly that many streams which are now intermittent then flowed all year. During excessive rains the soil was protected from erosion by native cover, and the vegetation responded by growing more luxuriantly to meet the demands of site protection during the next storm.

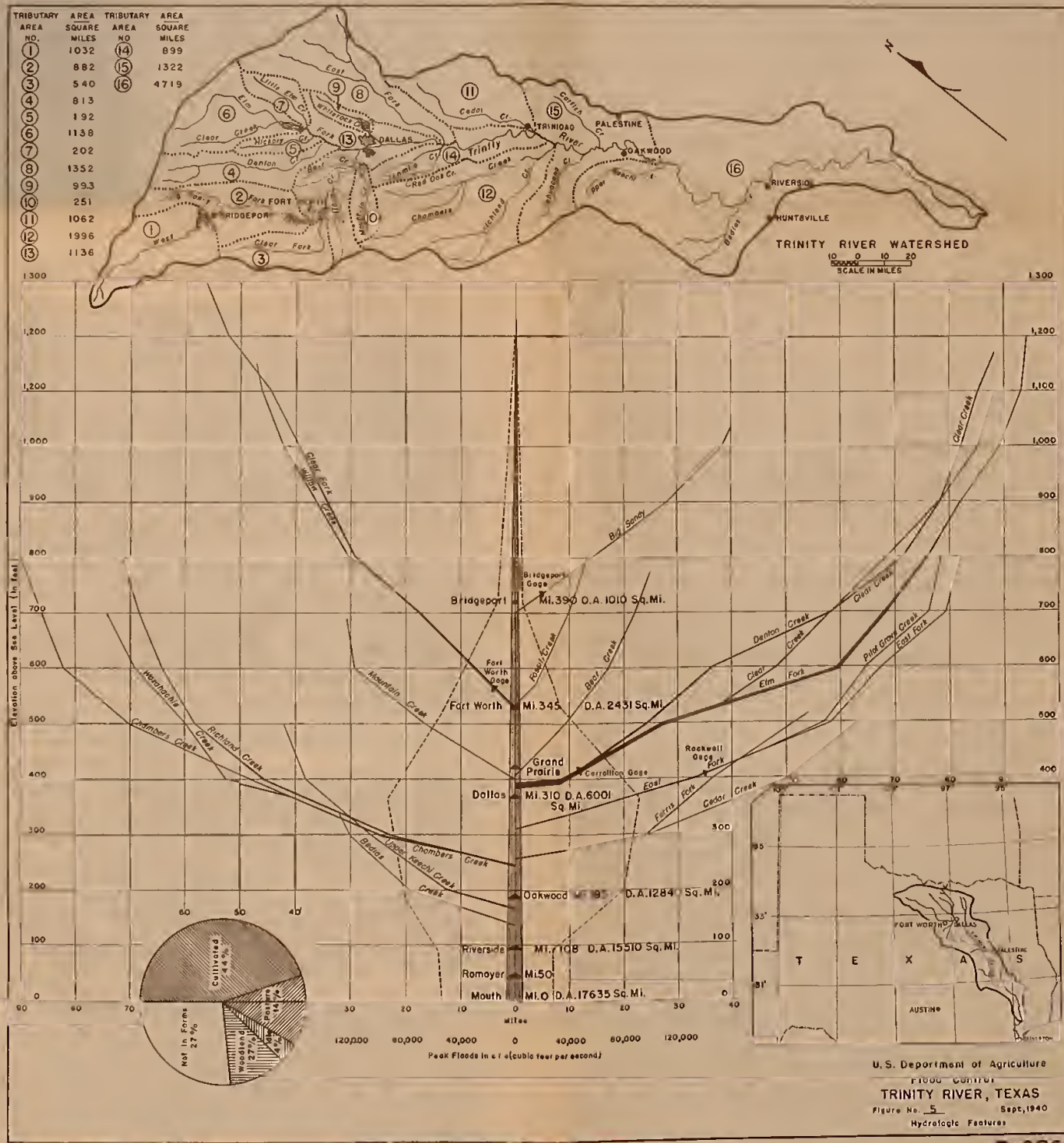
Today the Trinity and its tributaries are subject to frequent and rapid rises when rainstorms are heavy, and to greatly diminished flow, or complete drying up in some tributaries during periods of dry weather.

All major floods on the Trinity River are caused by storms covering two or more of the large tributaries, and the pattern of storms is such that the entire basin probably never will be covered to an excessive depth with rainfall. Storms moving to the north usually cross the watershed diagonally and lose a large part of their moisture before reaching the upper watershed. Storms moving in from the west might cover the headwater area, but records show that rainfall for this type of storm does not exceed 5 to 10 inches. Nevertheless, storms frequently cover several smaller drainage areas and even several major tributaries at the same time.[16]

Flood characteristics.—The configuration of the Trinity Basin as a whole is such that it does not produce unusually high rates of flow on the main stem of the river, although high rates are usual on the headwaters and tributaries. Nevertheless, severe flooding conditions exist because channel capacities have not increased since settlement, while the rate of run-off has increased materially.

Ordinarily, heavy rain alone is not enough to cause flooding, unless it is preceded by other rains which have soaked the ground thoroughly. Intensity of the rainfall is another factor. A given rain in a few hours

[15] Data from appendix D.
[16] See appendix B on hydrology.



U. S. Department of Agriculture
Flood Control
TRINITY RIVER, TEXAS
Figure No. 5 Sept, 1940
Hydrologic Features

(Faces p. 16)

U. S. GOVERNMENT PRINTING OFFICE : 1943 O - 71981

P-3260

will produce a much higher stage than the same quantity of rain spread uniformly over a longer period.

Extent and density of vegetative cover have a great influence upon the rate of run-off. Infiltration on the Trinity watershed varies with the season but not as much as it does on watersheds farther to the north, where freezing is a factor. On the headwaters above Fort Worth infiltration is aided by an underlying aquifer. The heavy soil of the Grand Prairie has comparatively small rates of infiltration and produces heavy run-off. The narrow belt of the East Cross Timbers, with wooded slopes and absorptive soils, underlaid by an extensive aquifer, has high infiltration rates, which hold down local flooding. The highly colloidal soils of the Blackland Prairie crack during protracted dry spells, and rainfall flows into the cracks until the soil is saturated, after which the infiltration rate becomes low. On the Gulf Coastal Plain, infiltration also is high at first, but diminishes after the ground is thoroughly soaked.

No flood of record on the Trinity has involved any great degree of synchronization of flood crests from tributaries. However, over extensive areas, especially on headwaters from Dallas upstream, synchronization of several tributaries has occurred frequently. When flows do join, extensive bottomlands are flooded on both the main stem and tributaries. The volume of the valley storage has been so great that during past major floods the crest has been reduced substantially as the flood wave moved downstream below Dallas. Floods in the upper part of the watershed usually are short because of the steeper grade and high velocity of the flow. As the grades flatten out near the coast, the periods of inundation are longer.

Above Dallas tributaries flood irregularly, but have averaged once a year over a 15-year period.

Practically every tributary of the Trinity below Dallas floods at least once a year. The frequency of flooding increases progressively downstream, with some tributaries flooding three to eight times a year.

The main stem of the Trinity River floods when one or two of the major tributaries are in flood. At Dallas the river reaches flood stage on an average of about once a year. Downstream, between Oakwood and Romayer, the stream floods on an average of twice yearly. Below Romayer, the river floods less frequently.

Figure 5 shows the stream pattern of the watershed, profiles of the major tributaries, and other features of the Trinity Basin as they relate to floods. The dotted lines shown on either side of the main stream indicate the relative contribution of the tributaries to main stream crest flow produced by concurrent flood conditions on the upper Trinity Basin.

Evaluated damages.—Flood damages on tributaries were evaluated only above dam sites considered by the War Department, and on tributaries where no structures have been considered. The value and distribution of flood damage are shown in figure 6.[17]

Direct damages from floods are estimated at $1,133,000 annually, of which 86 percent, or $975,000, is damage to agriculture. Non-agricultural damages amount to $158,000 a year, or 13.9 percent of the total. Damage to public roads, highways, and bridges accounts for 13.7 percent of the entire total, while railroad damages make up

[17] See appendix F for complete table on damages.

0.2 percent, and residential and municipal damages are less than 0.1 percent.

Of the $975,000 agricultural damage, nearly 70 percent is crop and pasture loss, or an average of $2.77 annually per acre of alluvial land. This damage varies from 27 cents an acre on the West Fork above Bridgeport where little land is cultivated, to $6.12 an acre on the intensely cultivated bottom land of Hickory Creek, a tributary of Elm Fork. Figure 7 lists damages by watershed problem area.

Other agricultural flood losses are damage to land by scouring and deposit of sand, loss of livestock and improvements such as fences and temporary buildings. Although the flood plain has been used for the production of crops and livestock, very few attempts have been made to build homes or other improvements there because of the constant flood hazard.

Flood damages which are not evaluated.—Floods cause considerable indirect damages which have not been estimated in dollars and cents Major overflows interrupt traffic on arterial freight and passenger lines, causing a delay in deliveries and rerouting of trains, busses, and private cars. Railroad and highway services are interrupted on an average of 1 or 2 days annually by this hazard.

Also in this class are losses of business income, rent of properties, and wages of employees in businesses or industries having to shut down because of floods and losses through interruption of power, light, and water services.

Floods have caused a marked decrease in fur-bearing animals and insect-eating birds.[18]

The spreading of noxious weeds is a troublesome flood problem. The greater part of the flood plain is becoming heavily infested with Johnson grass.

Loss of life as a result of flood has not been great. Records indicate that 31 persons have been drowned in the past 25 years. However, it should be recognized that additional deaths from flood probably have occurred, particularly in the lower reaches of the river, but have not been recorded.

FIG. 7.—*Estimate of present average annual direct flood damage to crops and pasture and to agricultural and nonagricultural property on the Trinity River watershed*

Tributary area	Crops and pasture	Agricultural property			Total	Nonagricultural property				Total agricultural and nonagricultural
		Land	Livestock	Farm buildings, fences, and other improvements		Public roads, highways	Railroads	Municipal	Total	
West Fork above Lake Bridgeport	$5,302	$577	$659	$659	$7,197	$659	0	0	$659	$7,856
West Fork between Bridgeport and Worth Lakes	27,051	13,451	2,069	2,897	45,468	3,363	0	0	3,363	48,831
Clear Fork	15,693	1,622	0	1,622	18,937	2,781	0	0	2,781	21,718
Denton Creek	35,073	3,816	908	1,726	41,523	4,883	0	0	4,883	46,406
Hickory Creek	22,533	6,618	764	2,545	32,460	1,432	0	0	1,432	33,892
Elm Fork above Lake Dallas Dam	76,545	18,904	2,660	7,140	105,249	18,859	0	0	18,859	124,108
Little Elm Creek	22,379	6,743	0	2,997	32,119	3,996	0	0	3,996	36,115

[18] See appendix I, the lower Trinity, for additional information on wildlife losses.

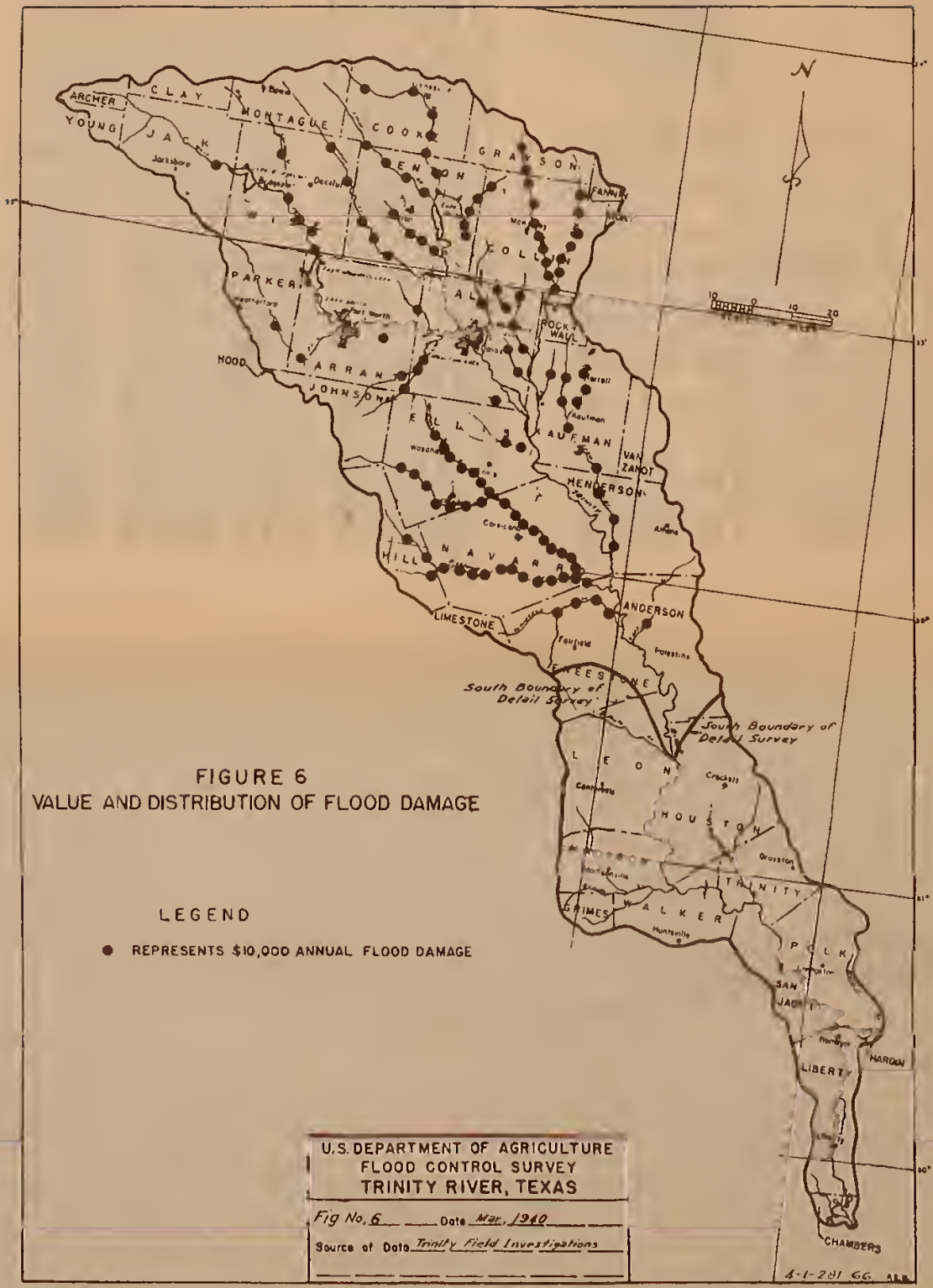


FIGURE 6
VALUE AND DISTRIBUTION OF FLOOD DAMAGE

LEGEND

● REPRESENTS $10,000 ANNUAL FLOOD DAMAGE

U.S. DEPARTMENT OF AGRICULTURE
FLOOD CONTROL SURVEY
TRINITY RIVER, TEXAS

Fig No. 6 Date Mar. 1940

Source of Data Trinity Field Investigations

4-1-281 66.

(Faces p. 18)

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FIG. 7.—*Estimate of present average annual direct flood damage to crops and pasture and to agricultural and nonagricultural property on the Trinity River watershed*—Continued

Tributary area	Crops and pasture	Agricultural property			Total	Nonagricultural property				Total agricultural and nonagricultural
		Land	Livestock	Farm buildings, fences, and other improvements		Public roads, highways	Railroads	Municipal	Total	
East Fork	$124,462	$24,927	$4,709	$16,618	$170,716	$30,005	$1,200	$150	$31,355	$202,071
White Rock Creek above reservoir	2,177	324	0	486	2,987	648	0	0	648	3,635
Bear Creek	8,202	474	0	1,020	9,696	1,186	0	0	1,186	10,882
Village Creek	1,978	222	0	258	2,458	369	0	0	369	2,827
Mountain Creek above reservoir	28,577	2,811	0	1,171	32,559	4,100	0	0	4,100	36,659
Cedar Creek	48,950	4,391	2,193	5,823	61,357	15,529	380	0	15,909	77,266
Chambers-Richland Creeks	295,173	25,540	4,594	16,532	341,839	56,053	500	0	56,553	398,392
Red Oak and Ten Mile Creeks	17,861	3,655	390	303	22,209	7,794	0	0	7,794	30,003
Tehuacana Creek	39,120	4,234	2,117	2,911	48,382	3,969	0	0	3,969	52,351
Total	771,076	118,309	21,063	64,708	975,156	155,626	2,080	150	157,856	1,133,012
Percent	68.1	10.4	1.9	5.7	86.1	13.7	.2	(1)	13.9	100.0

[1] Negligible.

WATERSHED PROBLEM AREAS

The drainage pattern of the river traverses the physiographic divisions of the watershed in a southeasterly direction. Several tributaries cut across two or more physiographic divisions and, with one exception, all tributaries cross two or more land-use-type areas. Since run-off, erosion, flood flows, and flood damages differ considerably from one tributary to another, the entire Trinity Basin has been broken up into its more important tributary watersheds, referred to as "watershed-problem areas," and indicated in figure 1. It is on the basis of these watershed-problem areas that the flood problem can best be determined and a remedial program most effectively developed and evaluated.

1. *West Fork above Lake Bridgeport Dam.*—This watershed, located in the westernmost part of the Trinity Basin, has a drainage area of 660,346 acres. The entire area is located within the West Cross Timbers, with 92 percent in the range-land area and 6.2 percent in the critical area. Lake Bridgeport comprises 1.8 percent of the area.

Seventy-nine percent of the upland area is in range and pasture, and 16 percent is in cultivation, most of it in the critical area. Most of the pasture is depleted, which permits rapid and excessive run-off.

Erosion has not been so rapid in this tributary as in others; yet considerable erosion has taken place, particularly in the critical area. The loss in net farm income due to erosion and depletion is estimated at $129,200 annually.[19]

Twelve percent of the flood plain is in cultivation and 77 percent is in pasture. Floods in this tributary inundate the flood plain for only a few days each year. Flood losess are low as compared with other tributaries. Sixty-seven percent of the total flood damage is to

[19] A discussion of methods of computing this loss is given in appendix E.

crops. The annual flood loss is $7,900.[20] Thirty-nine floods may be expected in 15 years. Some of the eroded material is deposited on the flood plain, but much sediment is deposited in Lake Bridgeport, reducing its storage capacity. This lake, built in 1932 by Fort Worth to supplement its system of water-supply reservoirs and to provide storage for flood-control purposes, is losing 0.28 percent of its storage capacity annually from siltation. The replacement cost due to sedimentation is inconsequential. If the Trinity should be canalized, this storage would increase in value, and all possible capacity should be maintained.

2. *West Fork between Lake Worth and Lake Bridgeport Dams.*— The watershed of the West Fork between Lake Bridgeport and Lake Worth covers 564,567 acres, including parts of the following land-use type areas:

	Acres	Percent
West Cross Timbers:		
Critical	388,798	68.9
Range land	50,067	8.9
Grand Prairie:		
Range land	105,787	18.7
Farm land	6,715	1.2
Area in lakes	13,200	2.3
Total	564,567	100.0

The critical area of the West Cross Timbers, almost 70 percent of this drainage area, is mostly in range and pasture uses, although much has been in cultivation at some time. Over half of the cropland in this area has been abandoned. Erosion losses are extremely high. The loss in net farm income due to erosion and depletion is estimated at $252,000 annually. In the flood plain approximately 39 percent of the land is in cultivation, and 45 percent is in pasture. Sedimentation has spread sand over practically all of 20,000 acres subject to flood, reducing crop yields by 10 to 90 percent.

Serious deposition has occurred on the minor tributaries, particularly on Big Sandy Creek, where the stream channel has been completely choked with sand. Clogged channels cause floodwaters to remain on the land for several days, seriously damaging the crops.

Lake Worth and Eagle Mountain Lake were built by the city of Fort Worth at the lower end of this watershed for municipal water supplies. These lakes have become important recreation centers for Fort Worth and the surrounding country, with boating, fishing, and picnicking facilities. A large number of summer homes have been built along the lake front.

Both lakes are now subject to sedimentation which will materially shorten their lives. The rate of sedimentation will increase if erosion continues unabated in the upland areas. The storage capacities of Eagle Mountain Lake and Lake Worth are being depleted annually at rates of 0.48 and 0.1 percent, respectively. The remaining life of Eagle Mountain Lake with the present sedimentation rate will be approximately 140 years. The increased replacement cost due to sedimentation amounts to $931 a year.[21]

[20] See fig. 7.

[21] Annual equivalent of replacement cost at 3½ percent interest 140 years hence.

Lake Worth, if destroyed by siltation, could not be replaced in an equally desirable location because of its easy accessibility and because of the residential development that has taken place on its shores. It is believed that the continued silting of this lake will impair these values to such an extent that within 30 years dredging will be necessary to maintain required capacity. The present worth of the annual cost of dredging, starting in 30 years, amounts to $11,861 annually.

The annual flood damage in this watershed is $48,800, including damage to crops and fields, loss of livestock, buildings, and fences. Thirty-eight floods may be expected in a 15-year period.

3. *Clear Fork.*—Clear Fork, the lower part of the western headwaters, has a drainage area of 345,937 acres, including the following land-use-type areas:

	Acres	Percent
West Cross Timbers, critical	98,585	28.5
Grand Prairie:		
Range land	216,102	62.4
Farm land	27,604	8.0
Alluvium (main valley only)	3,646	1.1
Total	345,937	100.0

Most of the uplands are in range and pasture. However, there is a substantial amount of land in cultivation in the critical area of the West Cross Timbers and the farm-land area of the Grand Prairie. Much land has been abandoned in the critical area. Erosion losses are heavy. The highly erodible critical area of the West Cross Timbers occupies almost 30 percent of the headwaters part of the watershed. During a minor flood in May 1939 samples of water from several creeks of the watershed had a suspended load varying from 2 to 7 tons of soil material per acre-foot of water.

Much of the eroded soil is deposited on flood-plain lands, thereby reducing the productivity of 10 to 15 percent of the area. Approximately 70 percent of the flood plain is in cultivation, 25 percent in cleared pasture, 2 percent in woodland, and 3 percent in farmsteads and roads.

The Texas & Pacific Railway built a water-supply lake at Weatherford in 1930. The original capacity of this lake, 311 acre-feet, is being depleted at the rate of 1.5 percent yearly, limiting its life to 46 years. The replacement cost arising from silt damage amounts to $1,315 a year.

There is a possibility that a flood-control reservoir might be constructed on this tributary. Assuming a storage capacity of 150,000 acre-feet, such a reservoir would be depleted at the rate of 0.28 percent annually, or 1 acre-foot of sediment for each square mile of watershed area.

This watershed has steep slopes and narrow stream valleys. "Flash" floods which rise rapidly, reach high discharge rates, and recede rapidly, are very common. Nineteen floods may be expected in 15 years.

Fort Worth lies at the confluence of Clear Fork and West Fork. Although the city is protected by a levee system, several municipal-park areas, a golf course, many small truck farms, and other developments are on the flood plain and exposed to flood damage.

4. *Denton Creek.*—Denton Creek drains 520,437 acres of the following land-use-type areas:

	Acres	Percent
West Cross Timbers:		
Range land	397	0.1
Critical	189,532	36.4
Grand Prairie:		
Range land	109,311	21.0
Farm land	157,737	30.3
East Cross Timbers	50,768	9.8
Blackland Prairie, normal	12,592	2.4
Total	520,437	100.0

Cropland comprises over 75 percent of the total acreage. Grazing is the most important land use in the range-land areas, which make up over 20 percent of the total acreage.

Erosion is severe in the critical area of the West Cross Timbers and moderate elsewhere. Most of the eroded soil is deposited on the flood plain, causing damage to approximately 35 percent of its total acreage. Productive capacity has been reduced 50 percent on approximately 5,650 acres, 40 percent on 830 acres, 30 percent on 480 acres, and 20 percent on 1,500 acres. The loss in net farm income attributable to erosion and soil depletion is estimated at $390,400 annually.

If a reservoir with a storage capacity of 200,000 acre-feet were built in the lower part of this watershed, the storage capacity of such a reservoir would be reduced 0.32 percent annually by sedimentation under present land use.

Stream channels in the upper half of the watershed generally are narrow and clogged with sand. In the lower watershed they are broader and unobstructed. During flood-producing storms, streams rise rapidly throughout the area. They recede slowly in the upper portion because of inadequate channel capacities.

This watershed has a special problem. Denton Creek flows into Elm Fork, the source of water for the city of Dallas. Turbid waters, which are the direct result of the erosion and flood conditions in the watershed, must be specially clarified before they can be given the regular purification treatment.

Flood losses consist of destruction of crop stands; reduced yields from delayed planting; damage to fences and other farm improvements; loss of livestock; and damage to roads and bridges. These are estimated to be $46,400 annually, of which 76 percent is crop damage. Twenty-four floods can be expected in 15 years.

5. *Hickory Creek.*—Hickory Creek is a watershed of 123,083 acres, lying between the Clear Creek and Denton Creek watersheds, composed of the following land-use-type areas:

	Acres	Percent
Grand Prairie:		
Range land	4,271	3.5
Farm land	75,713	61.5
East Cross Timbers	37,663	30.6
Blackland Prairie, normal	5,436	4.4
Total	123,083	100.0

The major part of the upland is in cultivation. Most of the remaining upland is in open and woodland pastures. Erosion losses are relatively low. The loss in net farm income due to erosion and soil depletion is estimated to be about $136,800 annually. Eighty-eight percent of the flood plain is in cultivation, largely in wheat and oats. Little damage is caused by deposition of eroded material in the flood plain.

Flood losses, of which 66 percent is crop damage, are estimated to be $33,900 annually. Thirty floods may be expected in 15 years.

6. *Elm Fork above Lake Dallas Dam.*—This watershed in the upper central part of the Trinity is a broad, fan-shaped area, with a network of tributaries which concentrate all drainage in Lake Dallas. The watershed of 728,015 acres includes parts of the following land-use-type areas:

	Acres	Percent
West Cross Timbers, critical	60,757	8.3
Grand Prairie:		
Range land	66,254	9.1
Farm land	293,957	40.5
East Cross Timbers	193,738	26.6
Blackland Prairie:		
Normal	32,390	9.8
Transition	71,327	4.4
Surface water (Lake Dallas)	9,592	1.3
Total	728,015	100.0

The principal use of the upland is for crops, although some is in cleared and woodland pasture. The net loss in farm income due to erosion and depletion is estimated at $705,700 annually.

Approximately 88 percent of the flood plain is in cropland.

Deposition of eroded material on valley lands below the critical area of the West Cross Timbers has created a serious problem. Approximately 30 percent of the area has been damaged by sedimentation.

Lake Dallas is subject to considerable sedimentation. This lake was built in 1928 by the city of Dallas for water-supply purposes at a cost of $5,281,000, of which $4,955,000 can be charged to water supply and conservation storage. Its storage capacity is being depleted at rate of approximately 0.72 percent annually, resulting in a replacement cost of $18,958 annually over the remaining 65 years of its life. It is probable that this rate of sedimentation will increase from year to year unless land-use practices in the upland areas are improved.

If a 200,000 acre-foot reservoir were constructed for flood-control purposes on Elm Fork above Lake Dallas its storage capacity would be depleted approximately 0.38 percent annually. The construction of such a reservoir would reduce the sedimentation rate of Lake Dallas from 0.72 to 0.34 percent annually.

In the critical area of the West Cross Timbers, where channels are choked with sand, floods rise rapidly and recede slowly as the channel cannot accommodate a high flood discharge. In the East Cross Timbers valleys are wide, but the channels are shallow and narrow and floodwaters frequently overtop the banks and flood bottomlands. In other areas channels are sufficient to carry high discharges, and

floods seldom last longer than a day. Thirty-six floods may be expected in 15 years.

Flood losses are estimated at $124,100 annually, 62 percent of which is crop damage.

7. *Little Elm Creek.*—This watershed, between Elm Creek and East Fork watershed, comprises 129,401 acres and takes in parts of three land-use-type areas:

	Acres	Percent
Blackland Prairie:		
Transition	10,932	8.4
Normal	111,134	85.9
Rough	7,335	5.7
Total	129,401	100.0

Both the upland and flood plain are in cultivation, and a small amount is used for pasture and woodland. Erosion losses in this drainage area are relatively heavy. The net loss in farm income, due to erosion and soil depletion, is estimated at $107,500 annually.

The heavy load of fine silt carried by floodwater in this watershed causes little damage when it is deposited on valley land, but much of this suspended material is emptied into Elm Creek and contributes to the turbidity problem of the Dallas water supply.

If a reservoir of approximately 50,000 acre-feet capacity were built on this tributary for flood control this storage would be depleted at an annual rate of approximately 0.91 percent.

The stream channels are clean and reasonably well defined. Floods rise more slowly than in adjacent watersheds and seldom cover the land for more than a day. Forty-eight floods may be expected in 15 years.

The total annual-flood damage is estimated to be $36,100, of which crop losses comprise 62 percent. Damages to highways, roads, and bridges make up approximately 11 percent.

8. *East Fork.*—The East Fork watershed is one of the major flood-problem areas of the Trinity Basin. It covers 865,306 acres, including parts of the following land-use-type areas:

	Acres	Percent
Blackland Prairie:		
Normal	514,951	59.4
Rough	305,995	35.4
Gulf Coastal Plain, normal	23,952	2.8
Alluvium (main valley only)	20,408	2.4
Total	865,306	100.0

The major land use is production of cotton and corn. In the flood plain 76 percent is in cropland, 14 percent pasture, and 5 percent woodland.

Erosion losses are high because the soil is highly erodible and because of extensive row-crop farming. The rough area of the Blackland Prairie, which borders the flood plain, suffers a major portion of the soil loss. Very little of the eroded material is deposited on valley lands during flood periods, as most of it is carried down the

main stem. The loss in net farm income from erosion and soil depletion is estimated at $798,300 annually.

The flood and erosion problem has created a serious threat to small reservoirs in this area. As shown below, sedimentation has practically destroyed the usefulness of two out of the three reservoirs in this watershed.

Reservoir	Year constructed	Annual siltation rate	Remaining useful life
New Farmersville	1935	1.0	55
Murphy Lake	1922	3.9	(1)
Cottonwood Reservoir	1912	9.4	(1)

[1] Extinct.

The increased cost of replacement of the New Farmersville Reservoir' due to sedimentation damage, is $236 annually.

If a flood-control reservoir of about 250,000 acre-feet capacity were constructed on the tributary below McKinney, its storage capacity would be depleted at the rate of 0.5 percent annually.

The stream channels are well defined, deeply incised, and free of debris. Minor floods recede in a few hours. Major floods, which frequently cover the flood plain to a depth of several feet, may last for 2 or 3 days. Seventy-eight floods may be expected to occur in a 15-year period.

A serious flood problem has been created by the levee system in this area. It is common for these levees to break or be overtopped during major floods; and water is impounded behind the levees and covers the crops for much longer periods than it does in fields between the levees. Chance of flood damage has been increased because the levee districts do not have sufficient funds for proper repair, maintenance, and drainage.

Flood losses are estimated to be $202,100 annually, 62 percent of which is crop damage and 15 percent damage to highways and bridges.

9. *White Rock Creek above White Rock Lake.*—This short tributary drains 63,568 acres, partly within the city of Dallas. The entire watershed is in the normal area of the Blackland Prairie.

Approximately 75 percent of the upland area is cultivated principally to cotton and corn. Approximately 36 percent of the flood plain is in cultivation, 34 percent is in woodland, and 30 percent is in pasture. The loss of net farm income due to erosion and soil depletion is estimated to be $48,300 annually.

Flood-plain deposition of eroded material is not serious since most of the silt load is clay and is held in suspension until it reaches the lake.

White Rock Reservoir, into which all of this watershed drains, was built in 1910 as a source of municipal water supply for Dallas, with an original storage capacity of 18,158 acre-feet. During the past 28 years the original storage has been reduced 24 percent. This rapid reduction and the growth of the city required the construction of Lake Dallas in 1927 in the adjoining Elm Creek watershed. At present, White Rock Reservoir is used only for recreation; however, its value for this purpose far exceeds the initial investment. Land values

within 2 miles of the lake shore amount to approximately $22,000,000. Were White Rock Lake destroyed by sedimentation, it is estimated that these values at present rates would decline about $8,000,000. Continual depreciation from swamping and shoaling will be suffered. In an effort to protect the investment in recreational facilities and property developments, the entrance channel and the head of the lake are dredged at regular intervals at considerable expense to remove the sediment that has been deposited. On the basis of a cost of $500 per acre-foot ($0.31 per cubic yard) for sediment removal, it would cost $78,000 annually to maintain this lake at its present capacity.[22] Local authorities consider this expenditure justified.

The stream channel is wide and free of debris and obstructions, except in the extreme lower portion, and permits floodwaters to recede rapidly. Fifty-four floods may be expected in a 15-year period. The flood loss is $3,600 annually, of which 60 percent is crop damage.

10. *Mountain Creek above Mountain Lake Dam.*—This small watershed drains 160,651 acres south of Fort Worth and Dallas. These land-use-type areas are represented:

	Acres	Percent
East Cross Timbers	34,371	21.4
Blackland Prairie:		
Normal	99,714	62.1
Rough	16,461	10.2
Escarpment	7,335	4.6
Lake surface (Mountain Lake)	2,770	1.7
Total	160,651	100.0

Crop production is the major land use in the uplands. Approximately one-fourth of the area is in pasture and woodland. Erosion and soil depletion cause a loss of net farm income estimated at $130,500 annually. Only a slight amount of the eroded soil is deposited on valley lands. Eighty-eight percent of the flood plain is cropland.

The 36,000 acre-foot storage capacity of Mountain Lake is being depleted 1.90 percent annually, and its impounded water has a high turbidity from the heavy load of suspended material carried by Mountain Creek during flood periods. Most eroded material is clay and is held in suspension until it reaches the lake. Mountain Lake, which receives all the drainage from this watershed, was built by private interests in 1937 at a cost of $1,755,000, for the production of electric power. Its potential usefulness probably will not exceed 30 years under present sedimentation conditions. The increased replacement cost arising from this sedimentation damage amounts to $33,800 per year.

Stream channels are clear and well-defined; hence the small overflows recede in a few hours. Twenty-eight short floods may be expected in 15 years.

Flood losses, 78 percent of which is crop damage, are estimated to amount to $37,000 annually.

[22] The average annual cost of $60,305, shown in appendix F, table 16, is based on present rate of expenditure, which will maintain capacity somewhat less than at present.

11. *Cedar Creek.*—Cedar Creek, on the eastern boundary of the Trinity Basin, includes 679,653 acres of the following land-use-type areas:

	Acres	Percent
Blackland Prairie:		
Normal	72,411	10.6
Transition	158,308	23.3
Gulf Coastal Plain:		
Normal	349,408	51.4
Rough	73,914	10.9
Alluvium (main valley only)	25,612	3.8
Total	679,653	100.0

Over 60 percent of the drainage area is in the Gulf Coastal Plain, and land use in the upland is rather evenly distributed between crops, pasture, and woodland. In the Blackland Prairie, which comprises almost 34 percent of the area, the uplands are mostly in production of cotton and corn.

Erosion losses are relatively high. The loss in net farm income from erosion, and depletion is estimated to be $315,300 annually. A small amount of eroded material is deposited on valley lands. The heavier eroded material clogs the stream channel.

In the flood plain 35 percent is in crops, 8 in cleared pasture, 57 percent in woodland and other. Much woodland is potential agricultural land, but cannot be developed profitably with the present flood hazard.

Rapid sedimentation jeopardizes a number of small lakes for municipal water supplies. These reservoirs and rates of depletion are:

Reservoirs	Original capacity	Annual siltation rate	Remaining useful life
Terrell City Lake	3,000	1.38	24
Kemp Lake	376	1.57	24
Mabank City Lake	295	.61	68
New Kaufman City Lake	445	.92	50
Old Kaufman City Lake	300	.80	18

Unless present land-use practices are corrected the above rates of siltation probably will increase. Replacement cost for four of these lakes amounts to $3,536 annually, due to sedimentation. Also inincrease of cost for water treatment for turbidity control is $682 annually.

Low gradients and clogged stream channels cause long floods in Cedar Creek, with serious damage to crops, making it unprofitable to develop additional fertile alluvial lands.

The estimated annual flood loss in the watershed is $77,300 of which approximately 63 percent represents damage to crops and 20 percent to highways and bridges. Eighty-three floods may be expected over a period of 15 years.

12. *Chambers-Richland Creeks.*—This watershed has two of the most extensive creeks and is the largest of the problem areas in the upper

Trinity. It drains a total of 1,277,228 acres, of the following land-use-type areas:

	Acres	Percent
East Cross Timbers	47,158	3.7
Blackland Prairie:		
Normal	623,594	48.8
Rough	256,303	20.1
Transition	307,704	24.1
Gulf Coastal Plain, normal	14,456	1.1
Alluvium (main valley only)	28,013	2.2
Total	1,277,228	100.0

Ninety percent of the drainage area is in the Blackland Prairie, in which the major land use is crop production, principally cotton and corn. A large part of the remaining area of the watershed is in cropland, although pasture and woodland are more prominent.

Erosion losses in this watershed are exceptionally high. Some eroded material is deposited in channels and on the flood plain. Much of it remains in suspension until it drops into the reservoirs or into Galveston Bay. The loss in net farm incomes from erosion and depletion is estimated at $1,210,053 annually.

In the flood plain, approximately 50 percent is in cropland, 11 percent in pasture, and 39 percent in woodland and other use. The flood hazard is responsible for the high percentage of undeveloped woodland.

There are a number of flood problems: (1) An attempt has been made to protect cleared flood-plain land by a series of levees. However, these are not high enough for major floods, and the water is impounded behind the levees and held longer than on unprotected lands. (2) Levees are exposed to considerable damage from floodwater and side-hill run-off. Because of the heavy costs involved, the levee districts are unable to properly maintain these improvements. (3) Lakes on tributaries of these two streams are being silted rapidly. Storage capacity of Dawson City Lake, originally 650 acre-feet, built in 1937 at a cost of $33,000, is being depleted at a rate of 2.0 percent per year. The original capacity of 7,350 acre-feet of Corsicana City Lake, built in 1921 at a cost of $330,000, is being depleted 0.5 percent per year. Replacement cost from sedimentation damage is $1,230 annually on these two reservoirs. The annual cost of treating water is increased $502 on the average because of its high turbidity, resulting from decreased reservoir capacity.

As much as 7 tons of soil is carried per acre-foot of discharge during flood periods. Should any reservoirs be planned on these watersheds, their storage capacity would be depleted by sedimentation at the following rates each year:

Assumed location	Assumed capacity	Annual sediment accumulation per 100 square miles of drainage	Annual depletion in storage
Lower Chambers Creek	100,000	200	1.6
Upper Chambers Creek	50,000	200	2.0
Waxahachie Creek	50,000	200	.7
Richland Creek	150,000	160	.7

The stream channels are narrow, of high gradient, particularly in the headwaters. Floodwaters concentrate quickly, and recede rapidly in the headwaters and more slowly in the main valley. Sixty-nine floods may be expected in 15 years. Total flood damages are estimated at $398,400 annually. Approximately 74 percent of the damage is to crops.

13. *Fort Worth and Dallas area.*—This watershed takes in the main stem of the Trinity River, and all of the tributaries drain into it between Lake Worth Dam and the confluence with East Fork. It covers a total of 727,243 acres and includes parts of the following land-use-type areas:

	Acres	Percent
Grand Prairie:		
Range land	9,614	1.3
Farmland	104,662	14.4
East Cross Timbers	177,037	24.4
Blackland Prairie:		
Normal	207,889	28.6
Rough	32,599	4.5
Escarpment	4,489	.6
Gulf Coastal Plain, normal	33,040	4.5
Municipal area, Fort Worth and Dallas	64,088	8.8
Alluvium	93,825	12.9
Total	727,243	100.0

Upland areas are used mainly for the production of cotton and corn, supplemented by small grains. Pasture and range are important except in the Blackland Prairie. Woodland is significant in the uplands only in the East Cross Timbers, the escarpment area of the Blackland Prairie, and the Gulf Coastal Plain.

Erosion losses in this watershed are relatively high. Most of this eroded material is carried directly downstream. The loss in net farm income from erosion and soil depletion is estimated to be $544,000 annually.

Floods and erosions give rise to an additional problem at Bachman Lake, on Bachman Branch, a small tributary of Elm Fork. This lake was built in 1903 by Dallas as a source of municipal water supply. By 1938 its original capacity of 2,300 acre-feet had been depleted one-third by sedimentation. The reservoir now is used only for reserve storage. Because of the location of the lake near the city, its value for recreation now far exceeds the original investment for the construction of the lake. Dallas has been growing steadily toward the lake, and many country estates and homes have been built in its vicinity. Present land values within 1 mile of the lake amount to approximately $3,000,000. Were this lake destroyed by siltation, it is estimated that this property value would probably decline to $1,500,000.

Tributary channels are relatively short, narrow, and steep. The main-stem channel is wide and free from obstruction. Floods on the small creeks recede rapidly with moderate flood discharges. Main-stem floods frequently last for several days. On the 2 main tributaries 25 floods may be expected in 15 years.

The location of Fort Worth and Dallas in this watershed creates special flood problems. Municipal parks and public utilities are

exposed to flood hazards. Marine Creek and Sycamore Creek flow through Fort Worth and cause considerable property damage.

Levee systems built by Fort Worth and Dallas are adequate for floods expected during a 25-year period. However, most other levees which have been constructed are not adequate, and crops suffer severe damage from drowning because floodwaters are impounded on the land by the levees. Major floods, particularly those that overtop the levees, damage the levees severely and necessitate costly maintenance each year. Few levee districts have sufficient funds to properly maintain the levees and, consequently, their effectiveness decreases with each major flood.

The erratic behavior of stream flow causes a serious sewage problem. Both Fort Worth and Dallas empty sewage into the stream. During flood periods diluted sewage is spread over the entire flood plain, and at other times stream flow is barely sufficient to carry it downstream. This creates an odor nuisance and a menace to public health. This problem is intensified by the fact that the refuse from several large packing houses in Fort Worth is emptied into the river.

Flood losses on Bear Creek and Village Creek average $13,700 annually. Seventy-four percent of the total is damage to crops and 13 percent to highways and bridges.

14. *Trinity River and Red Oak Creek.*—This drainage area below the Fort Worth and Dallas problem area, totals 575,084 acres, made up of the following land-use-type areas:

	Acres	Percent
Blackland Prairie:		
Normal	306,658	53.3
Rough	66,012	11.5
Gulf Coastal Plain, normal	139,183	24.2
Alluvium (main valley only)	63,231	11.0
Total	575,084	100.0

Approximately 65 percent of the area is in the Blackland Prairie, where crop production, principally cotton and corn, is the major land use in the upland. In the remaining upland outside the Blackland Prairie the land use is rather evenly distributed between cropland, pasture, and woodland.

The channels of Ten Mile and Red Oak Creeks, the main subtributaries, are well defined and inundation does not occur for long periods. Over a 15-year period 38 floods may be expected. Inadequate levees have increased damage to cropland by impounding water. High flood frequency has discouraged the development of much of the flood plain. Flood losses on Ten Mile and Red Oak Creeks amount to $30,000 annually, of which approximately 60 percent is crop damage.

Erosion losses are very high. Much of this soil loss is fine clay, which is carried to Galveston Bay. Deposition on valley lands is slight and damages are neither great nor permanent. The loss in net farm income, due to erosion and soil depletion, is estimated at $349,100 annually.

The original 900 acre-foot storage capacity of Kerens City Lake, on Rush Creek, is being depleted 1.06 percent each year. The remaining useful life of this reservoir will be limited to 52 years. Replacement

and water purification due to sedimentation costs amounts to about $580 annually.

15. *Tehuacana and Catfish Creeks.*—This watershed is the lowest part of Trinity Basin covered in the detailed survey. It drains 845,944 acres of the following land-use-type areas:

	Acres	Percent
Blackland Prairie:		
Rough	1,932	0.2
Transition	47,626	5.6
Gulf Coastal Plain:		
Normal	364,765	43.1
Rough	345,821	40.9
Alluvium (main valley only)	85,800	10.2
Total	845,944	100.0

Eighty-five percent of the watershed is in the Gulf Coastal Plain, and the uplands are divided evenly between crop production, pasture, and woodland. In the Blackland Prairie area, cropland is the major land use.

Erosion losses in this drainage area are relatively low. However, land in cultivation is highly susceptible to erosion. Most eroded material from such land is deposited in tributary channels and does not contribute appreciably to the deposition on alluvial lands. Loss in net farm income from erosion and soil depletion is estimated at approximately $307,000 annually.

Palestine and Wortham secure their water supply from surface reservoirs located on tributaries of the streams. Wortham City Lake, built in 1922 at a cost of $20,000 with an original capacity of 275 acre-feet, is depleted 0.4 percent each year. The Wolf Creek Reservoir of Palestine, of 222 acre-feet, is silting at the rate of 0.5 percent annually. Replacement and purification costs of these reservoirs increase about $200 annually during the remainder of their lives due to sedimentation.

Should a reservoir be constructed at any point in this watershed on tributaries, its storage capacity would be depleted at a relatively low rate. The main stem, however, carries a heavy load of suspended material from watersheds above Tehuacana-Catfish Creek, and any reservoir located there would be subjected to heavy sedimentation.

The low-gradient stream channels are usually blocked with eroded sand from upland areas and vegetation that has become established in and along the stream courses. This condition retards stream flow during flood periods. The more luxuriant and permanent vegetation in the uplands, which is characteristic of this area of relatively high rainfall, has retarded run-off of rainfall more than in other watersheds of the upper basin. As a result, stream flow is more tempered during storm periods. Also, many of the larger streams have a steady discharge of clear water throughout the remainder of the year. The floods rise slowly and generally last for several days, completely covering the alluvial land. As many as 86 floods may be experienced in 15 years.

The flood problems in this watershed are essentially the same as in areas immediately above it. A number of levees of the main stem, built by private levee districts, are of insufficient height to afford protection during major floods. Ineffectiveness of levees and the high

flood frequency have discouraged the development of much of the alluvial area otherwise suitable for crop production. Weed infestations, which follow flooding, have resulted in some abandonment of cleared land.

Approximately 44 percent of the flood plain is in cropland, and 56 percent is in woodland and other uses.

Flood losses are estimated to be $52,400 annually, 75 percent of which is crop damage.

Section III. Existing Activities Related to Flood Control

Any program for water-flow retardation and erosion prevention in the Trinity Basin must be integrated with programs under way or proposed by other agencies, which have a bearing on the flood and erosion problem. The program recommended in this report will complement the activities in aid of flood control carried on by other agencies.

War Department.—Investigations for stream regulation and improvement of the Trinity River were undertaken by the War Department as early as 1844. At the present time a detailed survey is being conducted on the Trinity River waterway. Conferences with the local district engineer of the Department indicate that a series of flood-control structures are being considered at strategic points along the Trinity. The War Department program, when coordinated with the water-flow retardation and erosion-prevention program of the Department of Agriculture, will result in a sound solution to present flood problems, and in addition will provide an opportunity for further agricultural and industrial development of the watershed.

Levee districts.—There are 44 levee districts, in which 1,705 landowners control 163,010 acres of the flood plain (*35*) (*39*). In 1936, 19 of these district levees were classed as good, 8 as fair, and 17 as poor or useless. Of the land inside the levees, 46,170 acres, or 28 percent, are uncultivated. Where levees are classed as poor or useless, districts do not have funds to repair or maintain the levees, thus increasing the frequency and extent of damage. The reduction in frequency and height of flood crests through the watershed improvement program probably will make a number of the levees more effective in protecting lands behind them and will encourage their repair and maintenance.

Most of the districts are insolvent. The 1936 average assessed value was $27 per acre and ranged from $5 to $200. This may be compared with an average debt per acre of $71, with a range of $3 to $630. The average tax rate was $9.48 per $100 valuation, and tax delinquency amounted to $17 per acre.[23]

Soil-conservation districts.—A law approximating the provisions of the standard soil conservation-districts-law was enacted by the Texas Legislature in 1939. Under this law, land-use regulations for a district can be made mandatory on favorable vote of a nine-tenths majority of landowners. About 90 percent of the watershed is covered by the nine organized districts and the four in process of organization, as shown in figure 9.

The soil-conservation districts are the local agency through which the Department of Agriculture will carry out most of its work in connection with a program of water-flow retardation and erosion prevention.

[23] Data from annual report of State auditor and efficiency expert, and from Levee Improvement Districts of Texas, State reclamation department, January 1937.

There is no act in Texas under which counties or other local units can enact or create rural zoning ordinances, grazing districts, or differential taxation.

County land-use planning committees.—Throughout the watershed county planning committees of farmers have been organized. These committees are developing a coordinated plan of desirable land use within their counties and cooperate with other neighboring county committees in bettering agricultural conditions. Various technical agencies of the Federal and State Governments cooperate, through the State land-use planning committee, in making available and assisting in collection and interpretation of necessary data, as well as advising the committees in order that the broader National and State interests will be coordinated with local interests.

Water-improvement districts.—Fort Worth and Dallas water-improvement districts have constructed large dams on tributaries of the Trinity for water supplies. These dams have a secondary effect of flood storage. It does not appear likely that any serious conflict of water rights will grow out of the application of a water-flow-retardation program on the drainage areas of these reservoirs. Tarrant County Water Control and Improvement District No. 1 has the right to divert 162,000 acre-feet annually from Lake Bridgeport and Eagle Mountain Lake, of which 52,000 acre-feet may be used for irrigation and 93,000 acre-feet for water supply.

Irrigation.—Investigation of irrigation on the watershed indicates that present activities of this nature have little or no effect on flood control. As far as known at the present time there are no plans for any large irrigation developments on the Trinity River.[24]

Trinity Improvement Association.—This organization has been active in advocating and promoting a soil conservation and flood-control program on the Trinity (*27*). The association can be expected to aid in furthering the objectives of a comprehensive flood-control program.

Texas Forest Service.—This agency has operated mainly on the timbered lands below the area of this survey, where an effective educational program to promote sound management practices has been under way for many years. A major activity has been the fire-protection program under the Clarke-McNary Act, providing organized protection to approximately 1,250,000 acres of privately owned forest land. As a result the annual burn has been reduced from about 10 to 1.5 percent annually. The work of this agency has materially improved the forest stand and reduced run-off and erosion from the timbered areas.

State highway department.—The methods of locating, building, and maintaining State highways have improved significantly during the past few years and have greatly reduced run-off and erosion along State-maintained roads. Adequate drainage ditches protected by vegetation and mechanical structure not only have protected many streams from sediment accumulation but also increased safety on the highways. An effort has been made to control storm run-off from roads. The general practice is to divert concentrated run-off on suitably protected areas adjoining roads, and to store some portion of it with drop-inlet structures at the larger culverts.

[24] An investigation of irrigation was undertaken by the survey party at the request of the United States engineers. See Irrigation, Present, and Potential, from the Trinity River, Tex., by Fred C. Scobey, Bureau of Agricultural Engineering, U. S. Department of Agriculture, 1939.

State research and educational agencies.—The Texas Agricultural Experiment Station, at its various substations, tests measures and practices of conservation. The results, along with those from the Department stations, are disseminated to farmers throughout the watershed through the State extension service, vocational-agriculture teachers, and the experiment stations themselves. Close cooperation and assistance of these agencies are needed to accomplish a program which depends on the treatment of upland farm areas to effect flood control.

The Soil Conservation Service.—(1) Demonstration project: Since 1935 a Soil Conservation Service demonstration project on privately owned farms has demonstrated the value of soil and water conservation methods and practices in the retardation of run-off and the control of soil erosion (fig. 9). Adjustment of land use, the use of vegetative and mechanical control measures, and the careful planning of cropping and management practices have been followed. With a small outlay of farm money, careful budgeting of labor, and adequate planning and technical supervision, it has been shown on 11,600 acres treated, that—

(1) Both soil and water conservation can be effected so as to increase infiltration, retard run-off, and measurably reduce soil loss.[25]

(2) The present downward trend in crop yields can be arrested and probably even reversed.[26]

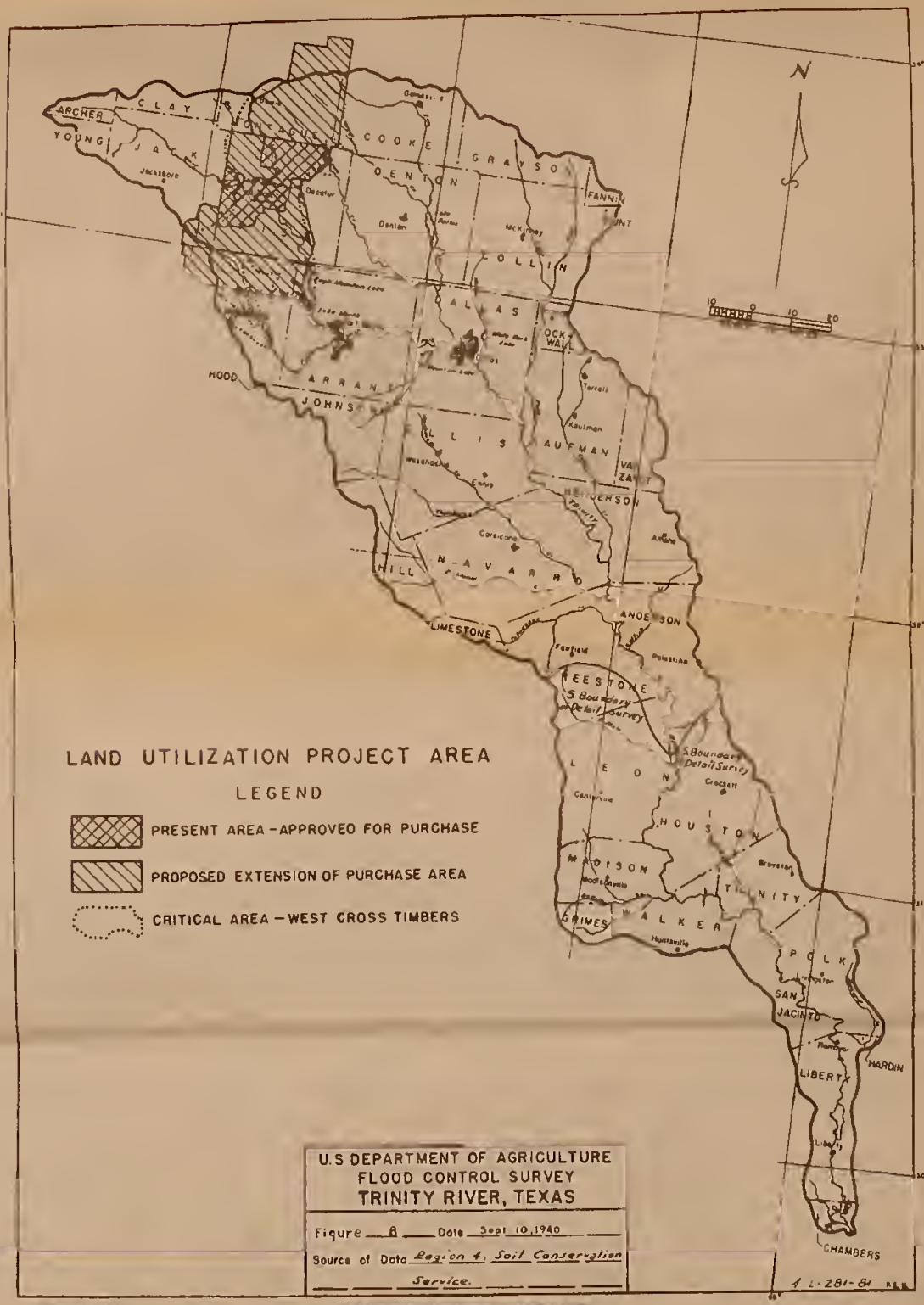
(2) Land-purchase project: The Cross Timbers land-utilization project, now under the administration of the Soil Conservation Service, was established in the critical area of the West Cross Timbers (fig. 8).[27] Approximately 13,000 acres had been purchased to February 28, 1940. The acreage is composed of severely eroded submarginal farm lands. These are being revegetated and so managed as to reduce materially the amounts of run-off and soil loss. It is anticipated that 24,000 additional acres may be purchased as a part of this already authorized project.

(3) Civilian Conservation Corps camps: Under the supervision of the Soil Conservation Service, seven Civilian Conservation Corps camps now are working on farm lands in soil-conservation districts or demonstration projects (fig. 8). To date 126,000 acres of farm land, approximately 1 percent of the entire watershed area, have been treated by these camps.

Agricultural Adjustment Administration.—About 90 percent of the farms within the Trinity watershed currently are being operated in cooperation with the Agricultural Conservation program (*44*) (*45*). One phase of this program is to protect and restore the fertility of the soil by enabling farmers to plant soil-building crops and to carry out soil-building practices. Conservation and soil-building payments have made it possible for many farmers to follow methods which contribute to water-flow retardation and erosion control.

This agency can assist in the watershed-improvement program by increasing the emphasis on land-use practices which will be most effective in a remedial program.

[25] Appendix B on hydrology gives detailed results.
[26] Appendix E gives details of effect of treatment on crop yields.
[27] Appendix H discusses the land-utilization project.



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Farm Security Administration.—Loans made by this agency to distressed farmers are based on farm plans which include recommendations that soil and water-conservation practices be followed.

The farm-debt-adjustment program, supervised by the Farm Security Administration, has scaled down numerous farm debts, thereby reducing the pressure for soil-depleting cash-crop production. It is estimated that about 3,000 farmers in the watershed were participating in this program in June 1938. With a greater number of farmers participating in the program of the Farm Security Administration and increased emphasis on the soil-conservation provision of the farm plans, operations of this agency may appreciably contribute to flood control.

Section IV. Recommended Watershed-Improvement Program

PRINCIPAL CONSIDERATIONS OF PLAN

The plan of improvement for the Trinity watershed recognizes that water-flow retardation and soil-erosion prevention can be realized only through significant changes in land use and farm management on a majority of the farms. Almost 90 percent of the area of the basin is in farms, and the success of the remedial program will depend on the extent of cooperation of farm owners and operators.

Most farm owners and operators doubtless feel that it would be desirable to use their lands in accordance with best land use and erosion-prevention practices, but as a group they have been financially or technically unable to make the readjustments necessary except where a public agency has assisted. It is recommended, therefore, that farmers be given the help and guidance they need by providing a definite and continuous program of education, technical aid, and supervision as a part of the remedial program.

Many cooperating farmers will need substantial assistance in order to install the complete program within the proposed 15-year period.

The amount of assistance will vary according to the financial status of the cooperators and the urgency of completing the program in a given area. This additional assistance will consist mainly of heavy equipment for terracing, ditch and pond construction, and special machinery for revegetation work; materials, such as seed, planting stock, and some construction materials; and labor, such as operators for machinery and auxiliary labor.

Federal funds are to pay for the following share of the work: (1) Construction of one-half the required terraces and diversion ditches; (2) construction of one-half the required terrace outlets; (3) revegetation of all areas to be retired permanently from cultivation; (4) revegetation of one-half the areas so severely eroded that they must be retired, at least temporarily, from further agricultural use; (5) construction of all farm ponds and smaller water-flow retardation dams.

The maximum Federal assistance will be made only as necessary to complete the program within the time limits. Every effort will be made to obtain the maximum contribution from cooperating farmers.

The practices recommended, the methods of their application, the effects, benefits, and costs of the recommended program, are outlined in the following pages.

REMEDIAL MEASURES

Farm-land treatment.—The remedial program of water-flow retardation and erosion prevention has been developed on a farm unit basis and involves (1) conversion of land to the use for which it is best adapted from the standpoint of good land use and flood control; (2) improvement in cropping systems; and (3) installation of mechanical structures.

Land conversions will include the shifting of critically eroding cultivated fields to pasture, meadow, or woodland use; and the restoration of all idle land to crop, pasture, or woodland.

Treatment of farm lands will consist of improvement in cropping, such as rotations using cover crops; contour cultivation, strip cropping, tree planting, sodding, and seeding; installation of terraces and so on. In the following pages both conversions and methods of treatment are discussed as they apply to various types of lands and conditions.

Measures recommended for cultivated land.—The constant and extensive growing of clean-tilled crops is the most hazardous land use from the standpoint of soil erosion and run-off. Major flood and erosion problems seldom arise in streams with well-vegetated watersheds. Much of the cultivated land in this watershed will require intensive use of measures to control erosion and run-off.

The type or intensity of treatment recommended is dependent upon several physical factors, as soil type, present erosion conditions, land slope, and the potential productivity of the soil. Inherent characteristics of each soil type or group of soils must be considered in a plan of control. However, certain over-all limits may be established. Cultivation should not be practiced on soils having over three-fourths of the top-soil removed by erosion, nor on slopes exceeding 4 to 8 percent. In certain cases slightly steeper slopes which are not eroded may be used for close-growing, fibrous-rooted crops.

Obviously, soils on steep and severely eroded slopes must be used only for permanent vegetation if run-off and erosion are to be controlled.

Crop rotation: This includes use of legume winter cover crops, to be carried out on all farms where the program is operative. This practice reduces soil loss and run-off, maintains soil fertility, increases the water-holding capacity, and renders the soil more resistant to droughts which occur frequently in the watershed. Results of experiments at Tyler, Tex., show that 3-year rotations which include cover crops, reduce soil loss to as little as 20 percent of the loss from continuous clean-tilled cropping (*1*), (*2*), (*7*).

Strip cropping and field stripping: All cultivated land, except bottomland, will be protected by strip cropping. Strips will be bands of close-growing, fibrous-rooted crops planted across the slope. Strips will be at least 18 feet wide when used in conjunction with terraces, and 30 feet wide on unterraced areas. They will be arranged to leave stubble standing for the greatest possible length of the time. Experiments under field conditions show that strip cropping reduces soil and water losses on short ungullied slopes (*1*) (*2*) (*7*). This measure is unusually supplemented by terraces on long slopes or on the more erodible soils.

Terraces: All cultivated fields will be terraced, except on overflow bottoms and the lower 200 or 300 feet of very gentle slopes, where no

gullying occurs. Terraces will be of variable grade, from 0 to 3 inches fall per 100 feet, with lengths not to exceed 2,400 to 2,600 feet. Generally they will be of the channel type constructed from the upper side. The cross-sectional area of the channel may vary from 16 to 10 square feet on slopes ranging from 2 to 8 percent. Ridge heights may vary from 14 to 18 inches on 2 to 8 percent slopes. Terraces will discharge water onto well established pasture, constructed sodded outlet channels, or into protected roadside ditches. Where roadside ditches must be used as terrace outlets, their protection will be undertaken as part of the recommended program. Outlet channels will be of adequate hydraulic design for a maximum velocity of 10 feet per second. Vegetated waterways will be seeded or sodded to adapted grasses. By decreasing effective slope length, terraces are highly efficient in reducing or delaying the rate of run-off and the total amount of soil loss. The Tyler station reports that doubling the length of slope on Kirvin fine sandy loam soil increased the soil loss one and one-half times (*1*). A terraced area yielded 78.2 bushels of corn, as compared with 55.4 bushels on a similar unterraced area.

Contour cultivation: This measure is recommended for all sloping cultivated land, and is effective in holding rainfall on the land and reducing soil losses. Contour cultivation will be used in conjunction with strip cropping and terracing where these measures are required. The Temple station reports that, in the Blacklands, rows up and down the slope result in severe sheet erosion which cannot be detected in these soils for several years (*2*). Rows up and down the slope at Guthrie caused soil losses more than double those from contour-cultivated fields (*7*).

Measures recommended for pasture and meadow lands.—The eroded, overgrazed, and trampled pastures on farms are in poor condition to provide soil stabilization and rainfall retention. Few meadows exist in the watershed, and it is recommended that where possible meadow strips be established to protect vulnerable areas. In order that these pastures and meadows can be of maximum value in protection, rather intensive measures are necessary, as follows:

Revegetation of critical areas: In gullied or severely eroded critical areas run-off will be diverted through the use of contour ridges, furrows, or terraces above the head of the area. Vegetation will be reestablished by bank sloping, seeding, sodding, and planting of shrubs and vines. Where necessary gully banks will be sloped and sodded, the bottoms to be seeded with Sudan grass, grain sorghum, switch grass, red top, or other adapted grasses or shrubs. Adapted shrubs and vines such as blackberry and kudzu, will also be used when possible and particular attention will be paid to the selection of food-bearing species for wildlife use. In some areas manure will be applied to speed up establishment of vegetation.

Diversion terraces: Where run-off damages valuable land below, or where headward erosion of gullies is severe, water will be diverted by means of intercepting terraces. Diversion terraces will be of a variable grade, varying from 0.2 to 0.5 foot fall per 100 feet. Velocities in these terraces will not generally exceed 0.5-foot per second for fine sandy soil and 4 feet per second for a stiff clay loam, and in all instances terraces should be capable of transporting silt in suspension without cutting the bed or banks.

Contour ridges: To hold rainfall on the thinly sodded pastures of the West Cross Timbers, East Cross Timbers, and the Gulf Coastal Plain, ridges or miniature terraces will be needed. They will be placed on the contour, spaced 9 to 12 feet apart, usually 12 to 18 inches high.

Contour furrows: This control measure will be used in depleted pastures and range lands to increase vegetation through conservation of moisture. The furrows will be constructed on the contour and spaced 4 to 5 feet apart, at a minimum depth of 5 inches and width of 12 inches. A middle buster plow is recommended for construction, due to the economy of operation and availability of the tool. Approximately an acre-inch of water will be stored on each acre so treated even after saturation of the soils.

Sodding: Pastures and meadows where present vegetation is scanty, and areas retired to these uses, will be revegetated by planting of sod pieces. Bermuda grass will be used in the Gulf Coastal Plain and the East Cross Timbers. Buffalo and Bermuda grass are recommended for the Blackland Prairie, and buffalo grass for the Grand Prairie. The sod will be placed in a well-prepared seedbed and protected until established.

Seeding: Adapted grass or legume seeds will be sown in meadows and pastures where needed. In the Gulf Coastal Plain and East Cross Timbers burr clover, switch grass, carpet grass, dallis grass, and red top will be used as needed. In the Gulf Coastal Plain 100 pounds per acre of a complete fertilizer will be applied at seeding. In the Grand Prairie and Blackland bluestem, rescue, side-oats grama, Texas grama, and buffalo grass will be seeded.

Firebreaks: Meadow or pasture fields, where exposed to fire hazard, will be protected by firebreaks. These will consist of plowed strips at least 6 feet wide, replowed twice annually.

Mowing and clearing: Weeds and brush will be controlled by mowing or clearing where they threaten the protective grass cover.

Cultivation: Pastures of Bermuda grass will be cultivated by disking, or by the use of other suitable devices, at least once each 5 years to maintain full vegetative vigor and cover for protection purposes as well as pasturage.

Measures recommended for range land.—The recommended program designed to control run-off and erosion on range land, and to maintain or increase grazing capacity, includes (*a*) controlled rates ofl stocking, (*b*) improvements in management, and (*c*) mechanica measures.[28]

Controlled rates of stocking: The badly depleted range must be restored by low or "recovery" stocking. After the range is restored by recovery stocking, grazing should be limited to "maintenance" stocking, the maximum number of livestock which may be grazed without damage to the range. An exception may be made in the post oak, blackjack-oak type of range, where initial heavy stocking by goats should be undertaken to eradicate tree sprouts. After this a small number of cattle or horses can be grazed and their number increased as the range is restored.

Improvement in management: Deferred and rotation grazing are essential parts of the improvement plan and can be introduced most effectively with the recovery stocking plan. Under ordinary ranch

[28] Details of effects of these measures are given in appendixes E and G.

conditions the ranch as a whole usually is fully stocked from season to season, and to defer grazing on any one pasture would cause an immediate shortage of feed in the others (*60*) (*61*). Under the provisions of this recommendation, however, this obstacle is overcome by initiating the system of deferred and rotation grazing at the time stocking on the ranch's pasture land is 30 percent below present stocking. Then, as increases in livestock numbers are indicated, the pastures not deferred will have sufficient feed available to carry the animals without difficulty, while accumulation is taking place on the deferred pasture. Once the plan is in operation, even under full stocking for the entire ranch, the amount and value of forage produced under a deferred and rotation system are greater than under full stocking over the whole ranch during the entire year.

Mixed grazing of cattle and sheep or goats is recommended for most range lands to control weeds and brush and to encourage the more desirable perennial grasses. Mixed grazing is most essential to pastures established on old timber sites where sheep and goats aid in keeping down weeds and woody growth.

Better distribution of grazing to avoid localized overgrazing and trampling will be attained by fencing, selection of salting, range feeding, and watering locations.

Forage-producing areas will be separated from wood-producing lands. Good pasture cannot be developed with an overstory of trees; neither can good woodland be developed with continuous grazing. In the range-land portion of the West Cross Timbers, within the post oak and blackjack oak type, clearing offers the greatest benefit. Here, if the overstory is removed, 71 percent of the present woodland-pasture area will carry the present numbers of livestock, with less deterioration of the site, and greater absorption of rainfall.

Within the West Cross Timbers, there are certain steep, barren, scarp areas, which deposit storm-washed silt, sand, and gravel on extensive flats below them. Where such "scarp" areas cause sufficient damage to justify the cost of fencing them off, they will be fenced and livestock permanently excluded.

Fire protection: On pastures where grazing is to be deferred until after seed maturity, a fire just before grazing might possibly wipe out the entire year's growth and damage the next year's growth as well by lowering the pasture's ability to absorb rainfall. Firebreaks will be plowed and maintained around borders of pastures. Education, regarding damages resulting from fires, will be a part of the program of protection from fire.

Contour furrows: Wherever necessary, water-retaining contour furrows or ridges will be built to retard run-off and thus to aid in establishing or restoring depleted stands of buffalo-grass or Bermuda-grass sod. Contour furrows also will be used in connection with most artificial reseeding projects.

Structures: Head cutting in gullies will be checked by water-diverting structures to prevent cutting back through productive swales and valleys. Herbaceous vegetation alone is unable to stop head cutting of gullies which have an abrupt drop-off at their head.

Measures recommended for farm woodlands.—In order to attain the desired woodland conditions, the following measures will be necessary and are recommended for the watershed as a whole, except as otherwise noted:

Fire-prevention education: The farm-woodland stands outside the Gulf Coastal Plain are so scattered and such a high percentage of the fires are willfully started by the landowners themselves that an organized fire-protection system would not be feasible nor effective. In these areas of scattered woodlands, fire-protection needs will be met most effectively through an educational program. This program can be coordinated with other educational programs involving direct contact with the landowner or operator, supplemented with periodic lectures, news releases, and the effective use of fire-prevention posters. Cooperative agreements between farmers and soil-conservation districts will provide that the farmers protect woodlands from burning and grazing.

Stand improvement: Present farm-woodland stands include trees which have no commercial value and probably never will be salvaged for fuel. These undesirable trees hinder the establishment and development of other types of greater commercial value. In the interests of increased income from timber areas, it is recommended that farmers eliminate the undesirable types by cutting or girdling and replace them with more desirable species.

Management: Management practices will be recommended to farmers to revise cutting methods and regulate the annual cut.

It is desirable that the annual cut be reduced to one-half the present annual growth until the stands reach full stocking. By permitting some cutting during this period, with emphasis on stand improvement, the general physical condition of the woodlands will be benefited; at the same time landowners will be able to obtain all or most of their wood requirements. Acre for acre, woodland thus managed would, after 48 years, produce 75 percent more wood than is now being produced under mixed wood and forage production. An allowable annual cut of two-thirds cord for each 10 acres would be available during the period required to reach potential production, after which an annual cut of 2.4 cords for each 10 acres could be sustained. Benefits in run-off and erosion control and improvement in wildlife habitat would follow within a year, reaching near maximum in 3 to 5 years.[29]

Grazing protection: Education will play an important part in the protection of woodlands from grazing. The evils of dual use and the necessity of excluding grazing animals from wood-producing areas must be carefully pointed out. Wooded areas will be fenced from grazed areas.

Planting: Complete planting will be limited to those areas converted to woodland from some other use and on which natural reproduction cannot be expected within a reasonable time. In the Blackland Prairie, rough, there are considerable areas of woodlands occurring on shallow, chalky soils which are poorly stocked and on which the establishment of natural reproduction is being delayed. These sites will not offer the best protection for many years unless artificially established reproduction supplements the natural growth. It is, therefore, recommended that these areas be interplanted to desirable tree species, preferably red cedar, which are well adapted to the poor sites.

Forest-fire control.—In the Gulf Coastal Plain, where woodlands are in relatively continuous blocks and are important commercially, the

[29] Effects of recommended management practices are shown in appendixes E and G.

Texas Forest Service has organized fire-protection units as far north and west as Palestine, Crockett, and the southern boundary of Madison County. Such fire protection is a cooperative program by the Federal Government, State, and landowners under provisions of the Clarke-McNary Act. As 50 percent of the total land area in the Gulf Coastal Plain is in timber, is is recommended that the State organization be extended northward to include the rest of this area. This extension will require the construction of fire towers, telephone lines, fire trucks and equipment, and the maintenance of additional fire-control personnel. It is recommended that two-thirds of the installation and one-third of the maintenance cost be paid from Federal funds and that the balance of the cost be contributed by State and local agencies. This protection will assist in conservation of forest cover on farm lands as well as commercial and private forests not protected through landowner-district agreements.

Public-land acquisition.—The most hazardous part of the Trinity watershed is the critical area of the West Cross Timbers, where advanced erosion and excessive run-off have ruined much land, threatened more, and contributed to serious flood and sedimentation on lands below. These sandy rolling lands have been riddled by gullies and devastated by sheet erosion. The soil never was fertile, and erosion has reduced its productive capacity to the point where the average farm family cannot make a living.

The remedial program recommended for this critical area includes (1) public acquisition of land that has been rendered wholly unfit for the support of farm families, and (2) treatment of this land to reduce run-off and soil erosion.

Progress already has been made along these two lines. A land-utilization project area has been established, involving a gross area of 175,000 acres within which purchase is authorized;[30] 13,055 acres had been acquired up to February 28, 1940 (fig. 8). The extension of the present purchase area is recommended as an important feature of the watershed-improvement and flood-control program. This calls for expansion of the gross area within which purchases may be made to 750,000 acres, and expenditure of $2,068,500 which it is expected will purchase 236,000 acres within this area.

Only those farms will be purchased which cannot be expected to support a family even though soil-conservation measures are applied. Such farms are eroding rapidly, much of their cropland is being abandoned, and continued cultivation will result in ultimate destitution of the operators. Most of this land must be converted to grass to preserve it. Farms of this type would be purchased, treated, and leased to nearby operators to enable them to build up units of adequate size. In order to lease these public lands farmers must agree to carry out conservation and proper land-use measures both on these and their own lands.

Purchase of these lands will require some of the families to move elsewhere. For them to remain where they are will result both in their ultimate destitution and the near destruction of the land they now occupy.

There are approximately 2,150 families living on the land proposed for purchase. These families will be classified according to their

[30] See appendix H.

capabilities, and assistance from appropriate agencies will be enlisted in (1) relocating those capable of farming, and (2) relocating the others in positions for which they are fitted.

Many of the older heads of families can be given life leases on the farms that they now own. Many others will be employed in the development program on the purchased land. A few will be employed permanently as caretakers, fireguards, and laborers and in other positions.

The purchase and development program will continue over a 15-year period; and it is believed that, with the work available on the purchase area and aid of the Farm Security Administration, population adjustments can be carried out gradually without serious disruptions.[31]

Treatment of land recommended for purchase.—The remedial treatment on the proposed 236,000-acre purchase area was developed from detailed plans made on 20 random sample farms, to provide maximum flood-control benefits at the earliest date. It is estimated that treatment will cost about $2,580,000.

Practically all of the land would be put to pasture but would not be grazed until a good cover had been established. In "early" areas this would require 3 to 5 years, in "intermediate" from 10 to 12, and in "late" from 18 to 25.

Small nursery plots would be established over the area on the better soils to provide a source of grass for revegetation. Mechanical treatments, such as contour furrowing, gully control, and other methods to control run-off and erosion would be applied where needed. New fence and cattle-guard lay-outs would be constructed to control grazing and protect the grass cover. Fire control would be carried out over the entire project, including maintenance of fireguards and removal of fire hazards, such as abandoned farm buildings. Truck trails would be laid out for patrol protection. Farm ponds would be built to supply water for livestock, so located as to encourage well-distributed grazing. Water facilities would include emergency water sources as a guard against drought. Ten caretakers' units would be constructed and maintained, including offices, telephones, power lines, and other items needed to provide supervision facilities.

Measures recommended for roadside-erosion control.—Control of roadside erosion is recommended as a cooperative undertaking by the Texas State Highway Department, soil-conservation districts, counties, and farmers whose lands are adjacent to State highways and county roads. No costs for roadside-erosion control have been included in the schedule of Federal expenditures for the remedial program, and no benefits have been claimed under the program for such work.

Where roadside ditches are the most economical outlet for terraces installed under the remedial program, one-half of the cost of constructing and protecting the outlet will be paid under the remedial program, and the balance will be shared by the landowner, and county or State highway department. The cost of such outlets has been included in estimates of terrace-outlet costs of the remedial program.

The Texas State Highway Department recently has developed a policy of roadside and drainage-erosion control on State and Federal-aid highways. Vegetation is used as much as possible as a means of stabilization, and all excavation and fill work is designed to aid stabil-

[31] See appendix H for a complete discussion of relocation of families within purchase area.

ization before damaging erosion occurs. An effort has been made to control storm run-off from roads by diverting run-off onto suitable fields adjoining the roads and to store some portion of the run-off in drop-inlet structures at the larger culverts.

It is recommended that all road-maintenance crews be instructed in proper use of grading equipment to preserve protecting vegetation.

Flood-control storage reservoirs.—It is recommended that Congress authorize the Department of Agriculture and the War Department to undertake a joint survey of the Trinity River watershed to determine the need for, and the engineering feasibility of, a system of small flood-control storage reservoirs on the tributaries of the rivers.

Hydrologic evaluation of the effects of the recommended remedial program on flood flows of the Trinity and its tributaries indicates that alluvial lands will continue to sustain some damage after the program is installed. The possibility of preventing these remaining damages by use of flood-storage reservoirs should be considered jointly by the War Department and the Department of Agriculture.

Preliminary consideration of the need for a storage program necessarily followed completion of the study of the requirements and effects of the land-use remedial program, from which developed the fact that not all flood-plain damages will be eliminated. A tentative appraisal was made of the flood-storage needs, which indicated that small storage reservoirs on minor tributaries, not affected by the tentative War Department program, would further reduce flood damages and would make possible a more complete utilization of the alluvial lands, to an extent justifying a joint investigation of flood storage as recommended.

Such an investigation should include a detailed survey of the physical and economic feasibility of such reservoirs, and a thorough appraisal of each probable dam site. Such an investigation could be undertaken while the watershed-treatment program is in progress, as the treatment program should be well advanced and sedimentation rates reduced, before any supplementary storage reservoirs are built.

GENERAL ADMINISTRATIVE PROCEDURE FOR CARRYING OUT THE PROGRAM

Farm-land treatment.—Soil-conservation districts: Remedial measures on farm land will be applied to a large extent by farmers themselves with the assistance of the Department of Agriculture, working through soil-conservation districts. These districts provide a responsible local agency to insure continuity and maintenance of the program, without which the expected benefits cannot be secured.

Farmers desiring assistance from the soil-conservation districts and the Department in carrying out measures for water-flow retardation and erosion prevention will sign an agreement with the district to carry out a farm plan which will extend over a period of 5 to 10 years and may be automatically renewed. The soil-conservation districts in the Trinity watershed approved by the State soil-conservation committee as of September 6, 1940, are shown on figure 9.

The costs of the remedial program and the benefits to be derived from it are based on an estimate of participation to be obtained, over a 15-year period, as shown in figure 10. This estimate was developed from field surveys and interviews with farmers, interpreted in the light of previous experience as to cooperation under the Soil Conservation Service demonstration projects and Civilian Conservation Corps projects.

Figure 10 indicates participation that may be expected, by land-use-type areas, under a soil-conservation-district program alone, in which the chief Federal contribution would be technical assistance in planning and supervision, as compared with participation which may be expected under both a districts' program and the Federal remedial program. Under a districts' program alone, it is estimated the the highest rate of participation in any area in 15 years would be 35 percent of all farm units. With both districts and the program of water-flow retardation and erosion prevention is estimated that highest participation in any area would be 80 percent.

Participation for the combined programs at the end of the 15-year period would vary from 37 percent in the critical area of the West Cross Timbers to 80 percent in the normal area of the Blackland Prairie. In the first area, low farm income, a high percentage of abandoned land, and related economic factors would make it difficult for a high percentage of farmers to participate. It is in this area that submarginal land will be purchased. In the latter area, the farmers still have a relatively higher income, the land is fertile, and erosion has not progressed to such a serious stage; thus more of these operators are able to carry out their part of the remedial program.

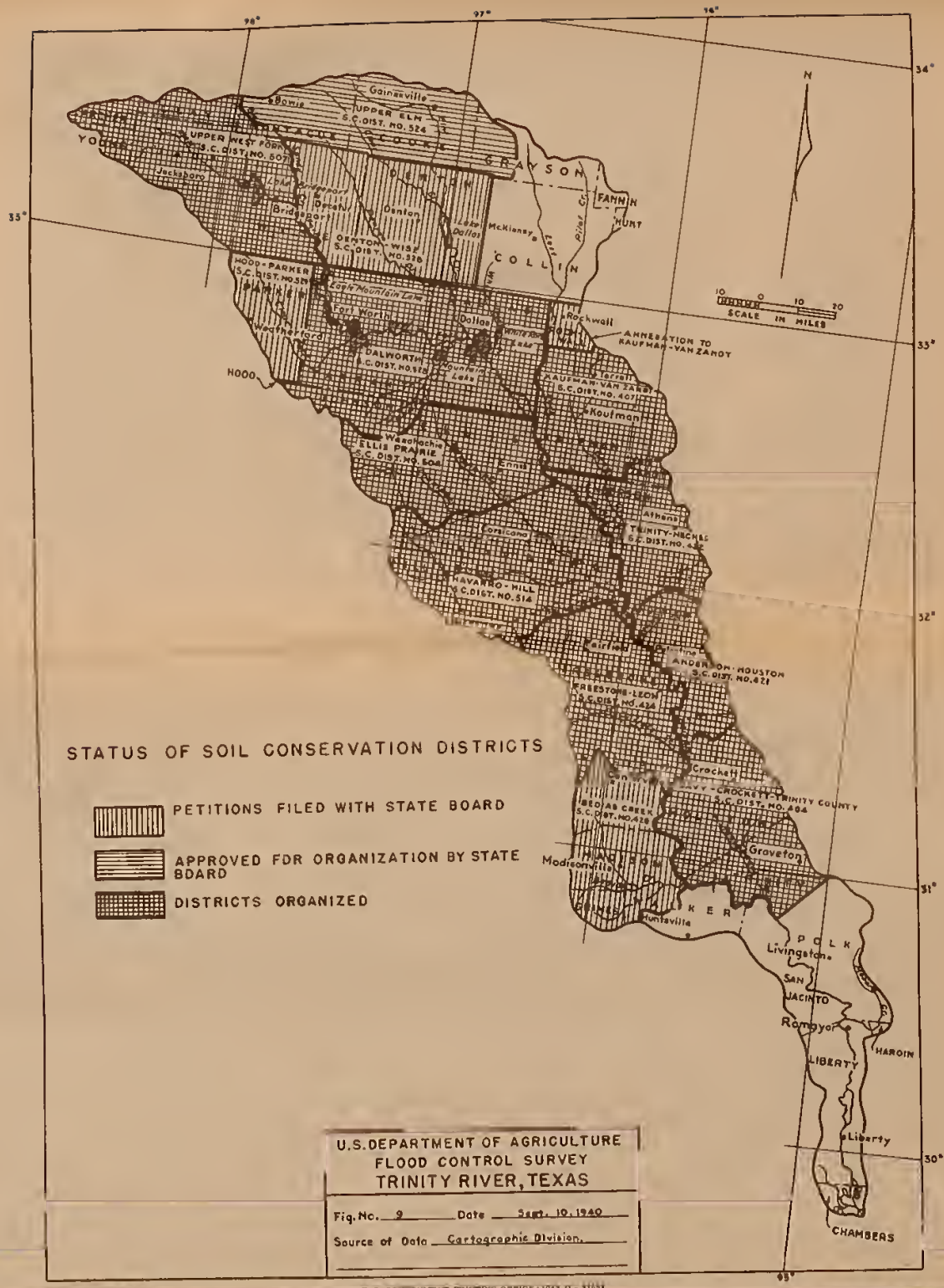
It will be noted that in 9 of the 11 land-use-type areas participation would be 50 percent or more of all units within the 15-year period.

Soil Conservation Service: The Department of Agriculture, through the Soil Conservation Service, will place trained technicians at the disposal of the cooperating soil-conservation-districts to help farmers work out farm plans for soil conservation and water-flow retardation, and will supervise the execution of the farm plans.

FIG. 10.—*Percentage of expected participation of farmers in soil-conservation work for different periods of the future under a soil-conservation-district program, and with the recommended flood-control program, Trinity watershed, Texas*

Land-use-type area	Percent of total farms expected to participate in program [1]					
	First 5 years		First 10 years		First 15 years	
	District program only	With flood-control program	District program only	With flood-control program	District program only	With flood-control program
West Cross Timbers:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Range land	10	35	20	75	35	75
Critical	3	22	6	37	10	37
Grand Prairie:						
Range land	5	75	10	75	15	75
Farm land	10	40	20	65	30	65
East Cross Timbers	3	45	6	55	10	55
Blackland:						
Normal	10	65	20	80	30	80
Rough	10	25	20	40	30	50
Transition	10	30	20	45	30	55
Escarpment	10	25	20	40	30	40
Gulf Coastal Plain:						
Normal	3	20	6	50	10	75
Rough	0	20	0	50	0	75

[1] Based on estimates of Soil Conservation Service area offices, assuming normal cooperation. These percentages of estimated participation under the recommended flood-control program are summaries and are for information only. Because they are averages with portional percentages dropped, they cannot be used for expansion of data or to determine the number of farms expected to cooperate or the acreage in the cooperating farms; nor to determine the public or private cost of the flood-control program. For methods and procedures used in determining the number of farms expected to cooperate in each tributary, the acreage in these cooperating farms, and the effect of the program on farms see appendix E. For methods and procedure used in determining costs and benefits of the program see appendix F.



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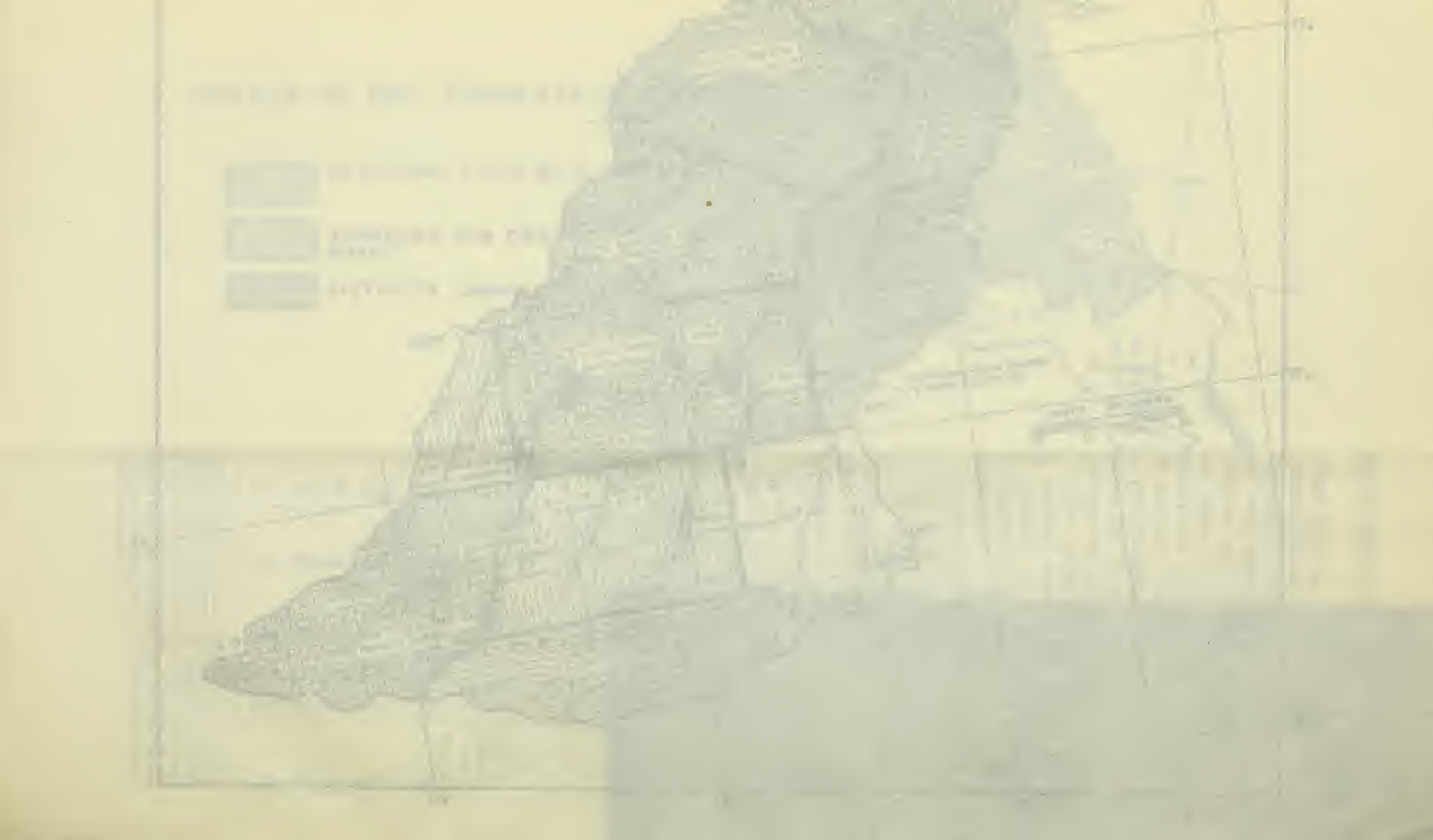

In cooperating with farmer members of the soil-conservation districts the Soil Conservation Service will encourage the use on the part of the districts of standard farm-lease forms developed in the Department of Agriculture.

Agricultural Adjustment Administration: Continuation of payments for carrying out soil-building practices as part of the program of the Agricultural Adjustment Administration will contribute toward completion of the watershed-improvement program. In order to obtain full benefit from these practices in the water flow and retardation and erosion control program it will be necessary for them to be applied in coordination with the plan of water-flow retardation and erosion prevention.

The farm-conservation plan under the 1941 agricultural conservation program provides that:

> In counties, groups of counties, or States, upon recommendation of the State committee and with the approval of the Agricultural Adjustment Administration, the net payment that would otherwise be made with respect to crop allotments for any farm in the county, group of counties, or State, as the case may be, shall be reduced by 5 percent for each 10 percent by which the producers on the farm fail to carry out during the 1941 program year that part approved for that year of a farm-conservation plan approved for the farm as one which, over a period of 5 years, will conserve the soil and increase its productivity. Such a plan shall provide for the carrying out on the various parts of the farm of soil-building practices needed for proper balance between the various crops grown, for the elimination of erosion hazards, for the restoration of the necessary humus to the soil, and other good land uses.

Cooperation with farmers to install the program of water-flow retardation and erosion control in a given soil-conservation district shall be conditioned on appropriate coordination with the agricultural-conservation program. Such coordination shall consist of (1) recommendation by the State committee and adoption by county committees of a farm-conservation plan, and (2) requirement that such soil-building and conservation practices provided under farm-conservation plans shall be in accord with those used in carrying out remedial measures under the program of water-flow retardation and erosion control. On a given farm the farm plan under which conservation payments are earned shall be in accord with the plan of water-flow retardation and erosion prevention for such farms as to types and locations of such practices.

Credit agencies: Farm plans used by Department credit agencies as a basis for loans to farmers in soil-conservation districts of the Trinity watershed in which flood-control funds are being expended will contain provision for water-flow retardation and erosion control in accordance with the remedial program.

Public acquisition of land and treatment of public land.—The acquisition, treatment, and administration of the land proposed for purchase in the West Cross Timbers critical area will be carried on by the Soil Conservation Service.

Forest-fire control.—Forest-fire control will be accomplished through an extension of the State-Federal cooperative fire-control system to the 400,000 acres of woodland in the Gulf Coastal Plain not now covered by the existing organization. Flood-control funds will be allotted to the Federal Forest Service for a cooperative forest-fire-control program under provisions similar to those used with Clarke-McNary funds, and under a cooperative agreement with the Texas Forest

Service. The Texas Forest Service will install and operate the fire-control facilities. Federal funds will be used to supply two-thirds of the installation costs for fire-control facilities, and approximately one-third of the annual operation and maintenance cost.

RECOMMENDATIONS FOR AUXILIARY MEASURES TO INCREASE THE EFFECTIVENESS OF THE PROGRAM

State agricultural extension service and agricultural experiment station.—A close relationship will be maintained between the Department of Agriculture and the State agricultural agencies in connection with the operation of the watershed-improvement program. The State agencies will be kept currently informed of activities being undertaken by the Department, and they should in turn bring to the attention of the Department information regarding new techniques and procedures which have been found to be effective in soil-erosion prevention and water-flow retardation.

County agricultural land-use planning program.—The State land-use planning committee and the county agricultural land-use planning committees in the watershed will be kept informed of the watershed-improvement program and the progress made.

Farm tenancy.—The flood control program in the Trinity watershed, where over 60 percent of the farms are operated by tenants who remain on a farm less than 2 years on an average, requires consideration of the extent to which the program will be affected by tenancy. Tenants cannot capitalize future benefits into present income to offset immediate installation and maintenance costs as is the case of landowners. Consequently, soil-conservation districts and county land-use planning committees should make every possible effort to work out principles for the most equitable division of costs and benefits between landlords and tenants, and to improve leasing arrangements so as to secure the benefits of the program for tenants as well as for landowners. State legislation should provide for minimum farm-leasing standards consisting of (*a*) automatic continuation from year to year of all agricultural leases unless notice for termination is served by either party not later than 6 months before the expiration date of the lease; (*b*) compensation for the unexhausted value of the present tenant's specified improvements when he quits the farm; (*c*) adjustment of the landlord's lien; (*d*) written agricultural leases; and (*e*) settlement of differences between landlord and tenant through arbitration.

Local units of Government.—Land use is affected directly and indirectly by the operation of local units of Government, through taxing, regulation, and public services. Consequently, a functional reorganization of such units can be of material assistance in bringing about improved land use. County agricultural land-use planning committees and soil-conservation districts might well take an important part in encouraging such action. Reorganization of local government could well include (*a*) provision for one assessment board and one tax collection agency for all units of Government in any county; (*b*) use of scientific methods of assessment under the control of the State land commission.

Tax-delinquent land.—State legislation dealing with tax-delinquent land is needed to provide (*a*) clear, simple, and enforceable procedures

dealing with tax delinquency and foreclosure; (*b*) means by which the State might gain or convey title to tax-reverted lands; and (*c*) a public land management agency which would classify State lands and assure their proper use in public control, or in private use, in case of sale or rental.

Levee districts.—Because of the frequency with which levees have been overtopped by floods, and the extremely poor financial condition of the levee districts, it has not been possible for them to repair or to improve many of the levees to give adequate flood protection to flood-plain lands behind such levees. However, if the remedial program is installed, the lowering of flood crests may make it economical for districts to repair levees, and to maintain them. If the program makes it possible for levees to be restored or improved, it will increase the flood-control benefits through reduction in flood damage to levees and to crops behind them, and in increased use of flood-plain lands behind now inadequate levees. It may be necessary for some districts to refinance their debt in accordance with their ability to pay before they can operate effectively.

Section V. Benefits of the Remedial Program

Installation and maintenance of the program as recommended will have the following effects and bring the following benefits to the public and to landowners of the Trinity watershed:

(1) reduction in flood damage

The proposed watershed-improvement program will significantly reduce run-off from all types of land in the upper Trinity watershed. Consequently the program will eliminate many of the smaller floods and reduce the size of the larger ones.

The flood-control benefits for the watershed-improvement program were computed only for tributaries. Wherever there was a possibility of a War Department flood-control structure on a tributary, benefits were not claimed below the probable location of such a structure.

The program will be particularly effective in reducing the damages from the smaller floods, which in the past have caused as much total damage as the upper limit floods. In summary the program is expected to reduce the aggregate total of acres inundated over a 15-year period by about 25 percent. In translating this reduction into dollars and cents the computation included factors such as duration of inundation, season in which floods occur, and the types of crops growing in the respective areas at the time of flooding. Based on these computations, it is estimated that total flood damage of $1,133,000 in the upper Trinity will be reduced by 53 percent. This reduction in flood damage thus amounts to a saving of about $598,000 annually in the flood plains for which benefits were computed.[32]

The classes of floods to be expected in the tributaries, on the basis of a 15-year record, are illustrated by the east fork in the example given below. Here are shown the number of floods within certain ranges of gage heights, the estimated number of acres inundated by each class of flood, and the extent of reduction in acres inundated

[32] See appendix, table F–15.

under the remedial program. It will be noted that the number of small floods far exceeds the number of larger floods, and that area of inundation from small floods is comparable, in the aggregate, with that from upper limit floods.

Reduction in acres inundated due to proposed program east fork, Trinity River

Magnitude of flood by stage height	Area inundated per flood present condition	Number of floods in each class	Area inundated per flood with remedial program in effect	Magnitude of flood by stage height	Area inundated per flood present condition	Number of floods in each class	Area inundated per flood with remedial program in effect
12.5 to 13.5	1,000	25		17.5 to 18.5	32,800	2	29,300
13.5 to 14.5	2,000	8	900	18.5 to 19.5	37,500	1	35,300
14.5 to 15.5	4,000	21	2,600	19.5 to 20.5	40.300	1	39,000
15.5 to 16.5	7,800	13	5,300	20.5 to 21.5	42,400	1	41,200
16.5 to 17.5	24,600	5	14,700	21.5 to 22.5	44,200	1	43,300

It should be taken into account that the effect of the program in reducing flood flows will vary according to particular conditions existing in each tributary watershed. The frequency of flood flows, gage heights, and acres inunadted are dependent in each tributary on factors such a channel capacity and grade, topography of the flood plain, and the manner in which the land is used.

(2) DEVELOPMENT OF FLOOD PLAIN LANDS

In addition to reduction of flood damage the remedial program also will encourage increased utilization of the flood-plain area. The rich alluvial soils are potentially the most productive in the Trinity Basin, but they are incompletely developed at present because of flooding. It may be assumed that additional development of this land will accompany reduction of flood frequency and size. In the tributary flood-plain areas included in this report are 390,000 acres of land, of which 62,000 are in pasture, 112,000 in idle land, woodland, or waste land, and 216,000 in cropland.

Any anticipation of increased intensity of agricultural use of the flood plains in the tributaries, must be predicated upon the experience of the farmers using the lands. This increased intensity of use will depend upon a demonstration to farmers of a decreased frequency of flooding as a result of the program over a period of years. Such a benefit must of necessity accrue after the program has attained maximum efficiency.

The benefits from increased use of the flood-plain land are to come from a shift of uses that now yield low net income per acre to crops yielding high net returns. Cotton acreage will be increased 47 percent and corn 51 percent; while very little change in acreage of wheat and oats will take place. Sorghum and hay acreage, on the other hand, will be reduced by a third, pasture by about a fifth. About 42 percent of present woodland acreage will be cleared for crops. In terms of percentage of the entire flood-plain lands now cleared this would be equivalent to adding about 23 percent more land to the present cleared acreage in the flood plain.

Development of tributary flood-plain lands will proceed over a 25-year period, and benefits from increased use will accrue progressively over a similar period. It is estimated that about 47,000 acres of idle land and woodland will be developed for high income yielding crops. Approximately 12,000 acres of pasture will be converted to cropland. Sorghums and hay will be reduced by about 9,000 acres by shifts to more profitable crops. Cotton would increase by around 36,000 acres, and corn by 31,000. It is estimated that flood-plain development made possible through the remedial program will result in an increase of $757,000 annually in net farm income.

The possible shift in use of flood-plain lands which may come about through reduction of the flood hazard is illustrated by the east-fork tributary, for which table F–13, appendix F, shows the number of floods by gage heights during a 15-year-period record, and the total acres inundated for each group of floods.

During the 15-year period, 78 floods occurred on this tributary, inundating an aggregate of 579,400 acres or an annual average of 38,627 acres. After installation of the watershed-improvement program, it is computed that the same number of floods over a 15-year period would inundate an aggregate of 421,600 acres, or an annual average of about 28,107. Thus, on this basis, in an average year approximately 10,500 acres of land, now subject to frequent flooding, will be released for more profitable use. It is estimated that about 8,300 acres of this area would become available for cotton, corn, wheat, and oats and about 2,000 would be usable for sorghums and hay, and other purposes.

Another method of analyzing the effect of reduction of flood hazards in this tributary confirms these results. Floods at a gage height of 22.5 feet inundate approximately 45,000 acres of land, of which 26,000 acres are in cotton, corn, wheat, and oats. Reconnaissance indicates that a large portion of this crop acreage is on higher ground and is not flooded frequently. If it is assumed that the remaining 19,000 acres lies in the lowest parts of the valley it can be determined from the stage-area inundated curve (fig. B–18, —) that this area will be inundated by a flood reaching a stage of 17.3 feet.

It is estimated that under the remedial program, a flood which now reaches a gage height of 17.3 would be reduced to one of 16.7 feet. According to the gage-height area-inundated curve for this tributary (fig. B–18, appendix B) this reduction in the flood height would decrease by 13,000 acres the area inundated, making it possible for farmers to use a large part of this area, formerly subject to frequent floods.

The estimate of increased use of tributary flood-plain lands is believed to be conservative. It is based on information as to the present use of levee-protected land and on information from farmers in the flood plain as to the present use of unprotected lands, and the conversions they would make if such land were protected from floods. With this information, it was possible to estimate the shifts in land use that would take place under the 53-percent reduction in flood hazards to be effected by the remedial program.

In determining the monetary value of increased use of the flood plain it was estimated that cotton yielded a net income of slightly over $25 per acre and corn around $12.50; while hay and pasture yield

respectively $10 and less than $3 per acre net per year. Obviously, if hazards should be greatly reduced on land highly adapted to cotton and corn, the shift from low- to high-income crops would be inevitable.

In figuring the values of such shifts, the cost of production was deducted and clearing costs were figured at $30 per acre, or an annual cost of $1.50 at 5-percent interest. Crops were priced at the normal prices used by the Farm Credit Administration in appraising land for long-time loans. No increase in crop yields entered in these calculations although the new cotton lands doubtless would be more fertile than the present flood-plain cotton lands which as a rule are the higher, sandier portions of the flood plain. The full effects of the stimulus of reduced hazards would not be realized for from 5 to 10 years (varying with different tributaries) after the installation of the conservation program is complete on the upland. The annual cash benefits are computed at slightly less than $907,000. When discounted for the 5–10-year lag and reduced to a present annual basis this benefit amounts to $757,000, mentioned previously, or slightly less than $2 net per acre per year for the 390,000-acre flood plain.

(3) REDUCTION OF SEDIMENTATION DAMAGE

The computed total annual rate of sediment production throughout the watershed is 62,000 acre-feet. Approximately 49,000 acre-feet of the deposition takes place annually in fields, flood plains, highway ditches, and other locations. The relative amount of deposition on alluvial lands is shown by the West Cross Timbers area, where approximately 1,200 acre-feet of sediment are deposited on the flood plains for each 100 square miles of drainage area.

The annual rate of deposition in the 21 reservoirs is computed to be 4,200 acre-feet. The annual sediment deposited in Galveston Bay is estimated to be 4,500 acre-feet. The rest, 4,300 acre-feet, is deposited in stream channels or leaves the drainage system.

Reductions in sediment by the watershed-improvement plan were calculated by field measurements and studies. Reservoir deposition would be cut down approximately 1,800 acre-feet annually, or 43 percent. As the average soil losses are reduced from 54 to 64 percent in the various tributary watersheds, it can be anticipated that all other deposition in fields, ditches, stream channels, and Galveston Bay, now amounting to 57,800 acre-feet annually, will be reduced 59 percent, or 34,000 acre-feet.

FIG. 11.—*Reduction in sedimentation due to watershed treatment of selected reservoirs, Trinity River, Tex.*

Name of reservoir	Original capacity	Annual storage-volume loss		Annual decrease in sediment due to treatment
		Without program	With program	
	Acre-feet	*Percent*	*Percent*	*Acre-feet*
Lake Bridgeport	292,000	0.28	0.14	400
Eagle Mountain Lake	211,000	.48	.33	313
Lake Worth	47,177	.10	.07	15
Lake Dallas	180,759	.72	.42	547
White Rock	18,158	.86	.45	75
Mountain Creek	36,000	1.90	.89	363
Terrell City Lake	3,000	1.38	.80	17
Corsicana City Lake	7,350	.53	.31	16
Bachman Lake	2,300	.91	.55	8
Weatherford Lake	311	1.51	.71	3
New Farmersville Lake	500	1.00	.60	2
Murphy Lake	397	3.93	(1)	----------
Cottonwood	30	9.40	(1)	----------
Old Kaufman	300	1.40	.47	1
New Kaufman	445	.91	.56	2
Kemp	376	1.57	.88	3
Mabank	295	.61	.34	1
Dawson	650	2.00	1.20	5
Kerens	900	1.06	.63	4
Wortham	275	.40	.02	1
Wolf Creek	222	.50	.27	1
Total	----------	----------	----------	1,777

[1] Filled.

The proposed remedial program would materially lengthen the life of reservoirs within the watershed by reducing the rate of sedimentation.[33] It is estimated that the annual benefit would be about $82,000 representing the money saved through reduction in the present replacement cost and dredging and water-purification expense.

Benefits are calculated on the basis of the continued use of Lake Bridgeport, Eagle Mountain Lake, Lake Dallas, and Mountain Creek for water supply. Present capacity is above demands, and reduction can occur over a long period before replacement of storage becomes necessary. However, if the Trinity River is canalized all present conservation storage will be essential to provide adequate regulated flow for navigation purposes. Any saving in storage capacity immediately would be beneficial.

If additional storage is to be provided, the remedial program would reduce the size of the proposed reservoirs necessary to maintain water yield for navigation. Also, natural-reservoir sites are limited and replacements can be made only at increasing costs as the more favorable sites are exhausted. When sites are exhausted capacity can only be maintained by high-cost dredging.

(4) REDUCTION OF SOIL LOSS

The annual rate of soil loss from farms within the 15 tributary watersheds of the Trinity is estimated to be 54,000 acre-feet, of which 59 percent could be saved by the remedial program. Soil lost from highways and other sources brings the annual yearly soil loss for the Trinity watershed up to 62,000 acre-feet.[34]

[33] Table 16, appendix F.
[34] See appendix C for details of computation of soil losses.

The effectiveness of the various remedial measures proposed in this report for the prevention of soil loss will vary according to the conditions of the individual tributary watersheds. The annual rate of soil loss from each tributary, together with an estimate of the annual soil savings that may be expected from land treatment, are shown on figure 12. The reduction of soil losses is greater than the reduction in deposition of sediment downstream, as not all transported soil materials reach stream channels, some being deposited on lower ends of fields.

FIGURE 12.—*Annual soil losses from farms and reduction expected through treatment, Trinity River watershed, Texas*

Watershed-problem areas	Annual loss	Annual saving through treatment	Percent of losses controlled by remedial program
	Acre-feet	*Acre-feet*	
West Fork above Bridgeport	2,904	1,856	64
West Fork between Lake Worth and Lake Bridgeport	6,746	4,323	64
Clear Fork	2,731	1,769	65
Denton Creek	4,954	3,012	61
Hickory Creek	849	451	53
Elm Fork above Lake Dallas	5,378	3,052	65
Little Elm	726	426	59
East Fork	5,277	2,843	54
White Rock above dam	329	211	64
Mountain Creek above dam	1,005	539	54
Cedar Creek	3,912	2,295	59
Chambers-Richland Creeks	8,075	4,343	54
Fort Worth-Dallas area	3,782	2,097	55
Trinity-Red Oak area	2,928	1,755	60
Tehuacana-Catfish Creeks	4,232	2,641	62
Total	53,828	31,613	59

(5) INCREASE IN FARM INCOMES [35]

An incidental, yet vitally important benefit from the program of waterflow retardation and erosion prevention, is the increase in crop yields and farm income which will follow the application of the remedial program. The total gross benefit which would accrue to the Trinity watershed, as a result of increased yields and increased farm income, is estimated to be more than $14,000,000 annually. This benefit was measured by comparing estimated average farm incomes both with and without the remedial program on a 25-year basis.

The effect of the program on farm organization.—The remedial program will result in these adjustments in land use on participating farms: (1) Restoration of all idle land to cultivation, pasture meadow, or woodland; (2) the shift of small acreages now used for crop production to pasture and meadow, and a small amount of woodland; and (3) clearing of substantial acreages of woodland for open pasture, mostly on pasture farms and ranches. There will be no radical changes in present farm organization, except in the purchase area. The restoration of all idle farm land will meet some obstacles such as unfavorable weather conditions at seeding time. However, the introduction of quick-growing cover crops and soil-building crops will aid in converting idle acreage to productive and soil-conserving use.

[35] See appendixes E and F for details of evaluation of this benefit.

The shift of small acreages of cropland to permanent pasture and woodland, temporarily will reduce farm output, but this reduction later will be compensated by increased pasture production. Those farms intensively engaged in the production of cash crops will adjust their land use to grow more feed and pasture requiring additional livestock.

In the Gulf Coastal Plain and both Cross Timbers areas, wood production will be separated from pasture. In the West Cross Timbers substantial amounts of woodland will be cleared for pasture. The increased carrying capacity of the cleared pasture will offset the reduction in forage on woodland, and no major change in the forage-producing capacity of these farm units will result.

During the first 5 years of the program range improvement will bring drastic curtailment of grazing and would materially change the livestock organization of ranches in the West Cross Timbers and Grand Prairie. However, after the program is developed, pasture and forage production will increase, and livestock numbers will exceed present levels.

Effect on incomes.—A few years after installation the program will result in substantial increase in net farm income in all areas and for all types of farms except ranches in West Cross Timbers and a few groups of pasture farms. At the beginning of the program about half the farms will receive increased net incomes, and about half will experience some decrease. This last group faces a decrease during the installation period because of shifts from cash crops to pasture, changes in livestock numbers, and other factors which delay income.

Crop farms respond most readily to the recommended treatments. About three-fourths of them will receive increases in average annual net income during the first 5 years of the program The increases in income on these farms average approximately $180, ranging from almost no change for those in the rough area of the Gulf Coastal Plains to over $850 for large row-crop farms in the Blackland Prairie area.

During the first few years of the program net farm income will be reduced on approximately half of the estimated number of cooperating farms. This temporary reduction in net farm income arises from such sources as (1) temporary reduction in crop production during the first few years of the program; (2) maintenance costs which are relatively high during the first 2 to 5 years of the program; (3) recommended shifts from cash crops to noncash crops; (4) increased investments in livestock and remedial measures; (5) temporary reduction in livestock numbers on ranches where overgrazing is marked; (6) reduction in sales from woodlands.

The income on all ranches, and most of the pasture farms in all areas, will be adversely affected during the development phase of the program. Adverse effects on income are most common on farms in both of the Cross Timbers areas and in the Gulf Coastal Plain. All groups of farms in the critical area of the West Cross Timbers will show an unfavorable balance during the first 5 years. These areas are seriously eroded, and yields have declined to such a level that the substantially increased yields expected under the program will not be sufficient to offset the expense during the early period of the program. Farm groups in these sandy, wooded areas are least able to stand any temporary reduction in income but are the ones most adversely

affected. These groups will be obliged to wait longest for conservation work to pay returns. In fact if the installation and maintenance costs are charged to them, the losses on some of these farms during the first 5 years will never be liquidated by the program.

Where income balance on farms during the first 5 years is unfavorable it is probable that substantially larger amounts of the installation and maintenance costs will have to be borne by public funds if the conservation and flood-control objectives are to be attained. Otherwise, many of these farms will not be able to participate in the program. It should be recognized, however, that if the work is done by the landowner using "slack season" labor on the farm, the cost may be less burdensome than the data indicate. From 80 to 95 percent of the installation cost is labor.

The reduction in net farm income varies widely from area to area and one type of farm to another. For example, during the first 5 years on crop farms which show a decrease such a loss ranges from less than $10 in the Grand Prairie, range-land area, to over $250 in the Blackland Prairie, rough area. The average loss for all crop farms which are adversely affected is approximately $75.

In all areas those farm groups dependent on pasture enterprises are at a disadvantage during the first 5 years of cooperation. The average annual loss for ranches is over $550, ranging from about $250 to over $1,000. The average loss for pasture farms is about $170, ranging from about $30 to about $325.

Long-time effects on farm income.—The long-time effect of the program on farm income generally is favorable.[36] Within 5 years after the program becomes fully effective, the expected increase in net farm income on about 22,000 farms will be sufficient to offset the losses in income and the farm share of installation and maintenance costs. On more than 1,500 other cooperating farms losses in income during the first 5 years will be repaid by increased income in 6 to 10 years after the program is fully developed and stabilized.

On about 1,200 cooperating farms, if the farmers are asked to pay all of their "allocated" installation and maintenance cost, 11 to 20 years will be required for the increased income resulting from the fully effective program to repay the cumulative losses of the first 5 years of the program. No farms require between 21 and 30 years of increased income to repay the 5-year losses. On about 1,100 farms, which occupy about 5½ percent of acreage on which cooperation is expected, 31 to 40 years of increased income from the program will be necessary to repay the 5-year losses. About 800 farms, on about 5 percent of the acreage, would never recover their losses. In fact, the increased income on these farms is not sufficient to pay 5-percent interest on the cumulative 5-year losses.

After the program is developed, farm-income increases will be relatively largest in the most productive cropland areas. The average increase for all farms in these areas is approximately $560, ranging from about $75 to $2,000 per farm. Pasture farms and ranches generally will get smaller benefits. Treatment costs will be relatively high on ranches, pasture farms, and woodland-pasture farms as compared with their present and potential returns under grazing or woodland uses. The average annual increase in net income for pasture farms is approximately $200, and that for ranches is $280.

[36] See appendix E.

Effect on tenants' income.—During installation of the program consideration will be given to the effects of the program on the individual tenant, since more than 60 percent of the farmers in the Trinity watershed are tenants, one-half of whom move every year. The temporary reduction in production of certain crops and recommended shifts from cash crops to a livestock pasture economy frequently will result in reduction of the tenants' income while benefits are delayed.

Since the normal tenant in the Trinity watershed is highly mobile, and since he has no means of capitalizing expected future benefits into present value, it is obvious that tenants cannot be expected to cooperate in the program if they have to pay for any part of installation costs other than normally included in farm operation. As a result of the program, farm income may decline for a few years but will recover, and finally increase over present levels, in the end making the land more remunerative to both landlords and tenants. However, even if tenants pay no part of the costs of the program, they will not gain during the early years in some areas, since they cannot capitalize future increases in income into present values to offset present losses, as can their landlord. The tenant's hope of gaining by the program will be enhanced if he can remain on the same farm sufficiently long to receive benefits from the program, through gains in the later years. Because of the situation of the average tenant, the program does not contemplate that as a rule the tenant will pay for any portion of the installation costs of the program other than in the course of normal farm operations. With proper educational work, both the landlord and tenant will realize that greater tenant stability will aid the installation of the program and will be financially beneficial to both of them.

Long-time effects on production.—Major crops and pasture: Without the program, it is estimated that the production of all crops and pasture will decrease appreciably below present levels within 5 to 15 years. Under the program, with the estimated participation, it is anticipated that the production of major crops will increase appreciably in 10 to 25 years. Hay production will increase about 30 percent and pasture more than 50 percent. Most of the increased production of pasture and feed would be consumed within the watershed. Wheat production will increase about 15 percent and corn about 4 percent.

It is estimated that cotton production will rise to around 502,000 bales, about 8 percent above the present level. This increase is due to substantial increases in yields expected on a 2-percent smaller acreage. Without the program it is estimated that cotton production will decline to about 382,000 bales, or approximately 18 percent below the present production.

Livestock and livestock products: It is assumed that the production of hogs, chickens, and turkeys will not be affected by the recommended program. However, cattle numbers will increase to approximately 411,000, or 53 percent above present numbers. Without the program cattle numbers probably would decline to about 92 percent of present numbers.

The larger number of cattle will increase the production of beef and butterfat above present levels, approximately 53 and 65 percent, respectively. It is assumed that most of the increased production of these two commodities will be sold rather than consumed on the farm.

(6) BENEFITS WHICH ARE NOT EVALUATED

In addition to the benefits which have been measured in dollars and cents, the proposed remedial program will bring a number of intangible but valuable improvements. Among these are (1) reduction in costly delays and rerouting of transportation; (2) increased infiltration rates, which will recharge the ground water, assuring a supply and lowering the cost of pumping for individuals and communities which depend on wells; (3) lower cost of public services in some areas by reduction of damages to roads, culverts, bridges, etc., by rapid run-off and erosion; (4) stabilized stream flow which will decrease sewage nuisance and cost of treatment; (5) improved wildlife habitats due to increased shelter for game and less danger from flood and silt-laden waters; (6) improvement of recreational areas and parks and their use through protection from flood damage; (7) decrease in the height of floods below levee crests which should encourage repair of broken levees and better maintenance of levee systems.

Section VI. Cost of the Program

It is estimated that the installation of the 15-year program recommended for the Trinity watershed will cost a total of $58,952,036, including both public and private expenditures, as follows:

Fig. 13.—*Total cost installation, operation, and maintenance of recommended measures, by source of funds, during period of installation of Trinity River watershed-improvement program*

Measures	Federal cost	State and local governments	Farmers and other individuals	Total cost
Farm-land treatment, including farmer maintenance	$27,172,000	$0	$26,657,504	$53,829,504
Treatment of land proposed for public purchase	2,583,475	0	274,088	2,857,563
Public purchase of land in West Cross Timbers	2,068,579	0	----------	2,068,579
Fire control	71,670	124,720	----------	196,390
Total	31,895,724	124,720	26,931,592	58,952,036

The cost of the program of water-flow retardation and erosion prevention was determined on the basis of flood-problem areas, which most commonly follow tributary watershed boundaries, because (1) the computation of flood damages was made on the basis of such areas, and (2) soil-conservation districts are being formed and will be administered approximately on a tributary-watershed basis. The individual farm was the primary unit in developing costs, and from detailed studies applying the program to sample farms, the costs of the program were computed for land-use-type areas and flood-problem areas.[37]

A memorandum of understanding will be entered into between each soil-conservation district and the Department of Agriculture, under which the district will agree to require maintenance of measures installed under the program of water-flow retardation and erosion prevention, through cooperative agreements with farmers on whose lands such measures are installed.

[37] Methods of developing costs are summarized in appendix F, including by farm types in each land-use type area (1) the needed land conversions, (2) the extent and cost of each treatment, (3) total cost, (4) average per-acre cost, and (5) distribution of cost between Federal and private funds.

After the 15-year period of installation, a maximum annual expenditure of $1,426,225 will be required for operations, maintenance, and replacement. This cost will continue thereafter and will be divided among farmers, Federal, State, and local governments as follows:

FIG. 14.—*Annual cost of operations, maintenance, and replacment after installation of Trinity River watershed-improvement program*

Measures	Federal cost	Non-Federal cost		Total cost
		State and local governments	Farmers and other individuals	
Farm-land treatment	0	0	$1,341,000	$1,341,000
Administration and maintenance of public land and land proposed for purchase	$19,000	0	[1] 54,275	79,275
Fire control	3,850	$8,100	0	11,950
Total	22,850	8,100	1,395,275	1,426,225

[1] Lessees of purchased lands will maintain remedial measures.

The cost of installing the program is summarized by flood-problem areas in figure 15, which follows, with a distribution of costs between (1) private individuals, (2) Federal Government, and (3) State and local governments.

The planning, installation, and supervision of the recommended program would extend over a 15-year period and would proceed at a variable rate, with expenditure of public funds required as shown in figure 16.

A break-down of the cost of the program is shown on a per-acre basis for flood-problem areas in figure 17. The private lands to be treated include 25,954 farms containing an average of 186 acres, or approximately 4,839,000 acres.

Soil-conservation camps and projects and private owners have already treated 130,255 acres. The Federal cost per acre for planning and supervision is $2.04, for installation $3.57, and private installation cost is $2.84. Variations in per-acre costs of treatment between tributaries are due to type of soil, slope, soil erosion, and other factors.

The 236,000 acres proposed for Federal purchase will cost $7.12 per acre which covers the cost of optioning, and the purchase price, while clearing title, planning supervision, and maintenance cost will be $4.88. Cost of installing treatment will be $7.71. There will be an annual administration charge of $0.08 per acre. Treatment costs are somewhat higher than in other parts of the watershed because of the critical condition of this land.

Federal installation costs will be expended approximately as follows: 48 percent for labor, 30 percent for equipment, 14 percent for transportation, and 8 percent for materials. Labor, which makes up a very important part of all costs, can be drawn in the main from relief or local sources, since such labor is suitable for much of the work.

FIG. 15.—*Public and private costs of flood-control measures recommended for the Trinity River watershed, by flood-problem areas, during period of installation*

Flood-problem area	Area to be treated				Period required for installation—Private purchase		Cost						
							On private land [2]		In purchase area [1]—Federal [2]	Fire control		Total	
	Private land	Federally purchased land	Total	Percent of all land in area	Land	Area	Federal	Private		Federal	State	Federal costs	Federal, private, and State costs
	Acres	*Acres*	*Acres*		*Years*	*Years*							
West fork above Lake Bridgeport	457,437	7,521	464,958	70	10	15	$1,277,900	$504,497	$148,398			$1,426,298	$1,930,795
West fork between Lake Worth and Lake Bridgeport	292,043	94,083	386,126	68	10	15	1,370,400	864,244	1,854,783			3,225,183	4,089,427
Clear Fork	197,785	43,261	241,046	70	10	15	609,800	291,236	853,055			1,462,855	1,754,091
Denton Creek	271,695	71,800	343,495	66	10	15	1,259,500	670,814	1,415,114			2,674,614	3,345,428
Hickory Creek	73,827		73,827	60	10		393,000	176,718				393,000	569,718
Elm Fork	438,950	19,311	458,261	63	10	15	2,090,400	1,105,743	380,704			2,471,104	3,576,847
Little Elm	91,943		91,943	71	10		666,800	267,331				666,800	934,131
East fork	550,875		550,875	64	15		3,862,400	1,809,146				3,862,400	5,671,546
White Rock Creek	47,445		47,445	75	10		378,200	144,885				378,200	523,085
Mountain Creek above dam	102,794		102,794	64	10		708,700	330,852				708,700	1,039,552
Cedar Creek	386,191		386,191	57	15		2,267,500	1,357,159		$23,650	$37,546	2,291,150	3,685,855
Chambers-Richland	789,738		789,738	62	15		5,231,300	2,485,348				5,231,300	7,716,648
Fort Worth-Dallas	349,343		349,343	48	10		2,110,200	1,069,130				2,110,200	3,179,330
Trinity-Red Oak	346,149		346,149	60	15		2,614,300	1,196,120		7,830	12,897	2,622,130	3,831,147
Tehuacana-Catfish	442,782		442,782	52	15		2,331,600	1,510,681		40,190	74,277	2,371,790	3,956,748
Total	4,838,997	235,976	5,074,973	61	15	15	27,172,000	13,783,904	4,652,054	71,670	124,720	31,895,724	45,804,036
Cost to farmers for operation and maintenance													13,147,688
Grand total													58,952,036

[1] Includes cost of land.
[2] Excluding costs to farmers of operation and maintenance.

FIG. 16.—*Federal costs of the flood-control program recommended for the Trinity River watershed, over a 15-year period, by years*

Year	Acreage to be treated		Cost of treatment			
	Private land	Purchase area	On private land	In purchase area [1]	For fire control	Total
	Acres	*Acres*				
First	280,898	23,603	$1,918,700	$465,199	$17,770	$2,401,669
Second	615,935	23,597	3,197,400	465,203	3,850	3,666,453
Third	732,763	23,597	3,439,300	465,204	3,850	3,908,354
Fourth	732,763	23,597	3,439,300	465,204	3,850	3,908,354
Fifth	732,763	23,597	3,439,300	465,204	3,850	3,908,354
Sixth	272,309	16,518	1,830,300	325,646	3,850	2,159,796
Seventh	272,309	16,518	1,830,300	325,646	3,850	2,159,796
Eighth	272,309	16,518	1,830,300	325,646	3,850	2,159,796
Ninth	272,309	16,518	1,830,300	325,646	3,850	2,159,796
Tenth	272,309	16,518	1,830,300	325,646	3,850	2,159,796
Eleventh	76,466	7,079	517,300	139,562	3,850	660,712
Twelfth	76,466	7,079	517,300	139,562	3,850	660,712
Thirteenth	76,466	7,079	517,300	139,562	3,850	660,712
Fourteenth	76,466	7,079	517,300	139,562	3,850	660,712
Fifteenth	76,466	7,079	517,300	139,562	3,850	660,712
All years	4,838,997	235,976	27,172,000	[2] 4,652,054	[3] 71,670	31,895,724

[1] Including cost of land.
[2] Annual cost of maintenance and supervision after 15 years, $19,000.
[3] Annual cost of maintenance and supervision after 15 years, $3,850.

FIG. 17.—*Number and acres of farms to be treated, acres already treated, average cost per acre of treatment, and proportion of Federal cost by classes of expenditures by flood-problem areas, Trinity watershed program*

Flood-problem (tributary) areas	Farms to be treated			Acreage already treated by Soil Conservation Service camps and projects	Average cost per acre of treatment			Percentage of Federal installation costs to be used for—			
	Number	Total acres	Average size of farm		Federal planning and supervision cost	Federal installation cost	Private installation cost	Wages for labor	Transportation	Purchase of materials	Equipment
			Acres					*Pct.*	*Pct.*	*Pct.*	*Pct.*
West fork above Bridgeport	873	457,437	524	--------	$1.48	$1.32	$1.10	52	8	3	37
West fork between Lake Worth and Lake Bridgeport	1,126	292,043	260	6,524	2.05	2.64	2.96	55	10	7	28
Clear Fork	613	197,785	323	--------	1.52	1.57	1.47	55	10	7	28
Denton Creek	163	271,695	234	7,696	1.93	2.70	2.47	55	10	7	28
Hickory Creek	372	73,827	198	1,175	2.37	2.95	2.17	55	10	7	28
Elm Fork above Lake Dallas	2,383	438,950	184	5,833	1.79	2.97	2.52	55	10	7	28
Little Elm	483	91,943	190	--------	2.45	4.81	2.91	45	15	10	30
East fork	3,782	550,875	146	46,303	2.04	4.97	3.28	45	15	10	30
White Rock above dam	335	47,445	142	--------	2.63	5.33	3.05	45	15	10	30
Mountain Creek above dam	679	102,794	152	--------	2.19	4.71	3.22	45	15	10	30
Cedar Creek	2,660	386,191	145	27,800	2.04	3.83	3.51	45	15	10	30
Chambers Richland Creek	4,702	789,738	168	34,444	1.99	4.63	3.15	45	15	10	30
Fort Worth-Dallas area	2,122	349,343	183	500	2.15	3.89	3.06	55	10	7	28
Trinity-Red Oak area	1,996	346,149	173	--------	2.60	4.95	3.46	45	15	10	30
Tehuacana-Catfish Creek	2,665	442,782	166	--------	2.54	2.73	3.41	43	23	4	30
Total private lands	25,954	4,838,997	186	130,255	2.04	3.57	2.84	48	14	8	30
Purchase area	1,945	235,976	121	--------	4.88	[1] 14.83	------	77	8	10	7
Fire control	-------	400,000	------	--------	------	[2] .06	------	----	----	----	----

[1] Includes the purchase price per acre of $7.12. There is also an annual administrative cost of $0.08 per acre.
[2] In addition to this cost, there will be an annual maintenance cost of $0.03 per acre.

COMPARISON OF COSTS AND BENEFITS

Annual costs of the program cannot be compared directly with annual benefits unless both are reduced to an annual equivalent on the basis of present values. Expenditures during the course of the remedial program will proceed at a variable rate by years. Benefits also will accrue at varying rates and not in proportion to rate of expenditure. Therefore, to express benefits on a comparable basis with costs, they were discounted to values at the time of installation. Maintenance costs were similarly discounted to values at the beginning of the program. All costs and benefits then were converted to an average annual equivalent.

It is estimated that the remedial program will cost an annual equivalent of $5,477,564, as compared with benefits of $15,800,041, giving a ratio of $2.88 in benefits for each $1 of costs.[38]

The total average annual Federal contribution will amount to $965,710, as compared with the equivalent of $4,503,389 contributed by owners of land in the form of interest on installation expenditures, annual maintenance costs, labor and materials, loss of income, and increase in regular farm expenditures.

Off-site benefits will amount to $1,437,673, or $471,963 annually, in excess of Federal costs. Benefits to lands on which work is carried out amount to $14,362,368 annually, as compared with $4,503,389 of costs to be borne by farmers.

The ratio of benefits to costs varies greatly among the 15 tributary areas. The lowest returns from the remedial measures will be those in the Clear Fork area, where benefits total $1.60 per $1 of costs. The maximum benefits will develop in the areas above White Rock Dam, where benefits are $3.70 per $1 of costs. In 8 of the 15 flood-problem areas, benefits will exceed $3 per $1 of costs; in 5 areas, they will be from $2 to $3; and in the remaining 2 areas, benefits will be $1.60 and $1.68.

Figure 18 summarizes the annual equivalent of costs and benefits, by type of expenditure and benefit. Figure 19 summarizes the annual equivalent costs and benefits and the ratio of costs to benefits, for each flood-problem area. Figure 20 presents a detailed break-down, by flood-problem areas, of estimated Federal, State, and farmer costs of the various remedial measures, and the estimated value of each type of benefit, expected to result from their application.

In view of the relatively large benefits which will result in all flood-problem areas in the watershed, and the high average return for the program on the entire Trinity watershed, the program as a whole is well justified and is recommended accordingly.

[38] A complete break-down of costs and benefits by type of expenditure, source of benefit, by tributary area is given in appendix F.

FIG. 18.—*Annual equivalent of costs and benefits of the flood-control program recommended for the Trinity River watershed, by sources*

Item	Annual equivalent of present worth	Item	Annual equivalent of present worth
Annual cost of program:		Annual benefits from program:	
Federal funds:		Flood control:	
Installation and supervision of treatment of private farm land	$815,160	Reduction of recurrent flood damage	$598,221
Land purchase, treatment, and administration	146,167	Increase of net farm income from changes in use of flood plain	757,034
Fire control on private land	4,383	Reduction of reservoir sedimentation	82,418
Total	965,710	Total	1,437,673
State funds: Fire control on private land (total)	8,465		
Farmer contribution:		Conservation:	
Installation and maintenance	2,192,666	Gain in gross farm income and decrease in farm expenses	14,134,589
Loss of gross income and increase in regular farm expenses	2,310,723	Rental income and gain in income to purchase area	227,779
Total	4,503,389	Total	14,362,368
Total costs	5,477,564	Total benefits	15,800,041
		Ratio of cost to benefit	2.88

FIG. 19.—*Annual equivalent of costs and benefits of the flood-control program recommended for the Trinity River watershed, by flood-problem areas*

Flood-problem area	Annual cost	Annual benefit	Benefits per dollar of cost
West Fork above Lake Bridgeport	$160,717	$349,040	$2.17
West Fork between Lake Worth and Bridgeport	297,400	499,801	1.68
Clear Fork	216,245	346,966	1.60
Denton Creek	335,395	774,187	2.31
Hickory Creek	74,892	268,921	3.59
Elm Fork above Lake Dallas	489,341	1,460,306	2.98
Little Elm	110,708	372,385	3.36
East Fork	703,262	2,201,638	3.13
White Rock above dam	60,981	225,769	3.70
Mountain Creek above dam	122,959	452,995	3.68
Cedar Creek	531,067	1,683,515	3.17
Chambers-Richland area	1,005,436	3,614,566	3.60
Fort Worth-Dallas area	380,505	1,148,971	3.02
Trinity-Red Oak area	501,277	1,406,595	2.81
Tehuacana-Catfish Creeks	487,379	994,386	2.04
Total	5,477,564	15,800,041	2.88

FIGURE 20.—*Federal, State, and farmer contributions to costs of recommended remedial measures, and benefits expected to result from the measures by flood-problem areas, Trinity River watershed*

ANNUAL EQUIVALENT OF COST OF PROGRAM

Flood-problem area	Federal contribution				State contribution		Farmer contribution		All costs
	Installation and supervision on private farm land [1]	Fire control on private lands [2]	Purchase of land and treatment and administration of land purchased [3]	Total	Fire control on private lands [4]	Installation and maintenance [5]	Loss of gross income and increase in regular farm expenses [6]	Total	
1. West fork above Lake Bridgeport	$38,337		$4,660	$42,997		$69,661	$48,059	$117,720	$160,717
2. West fork between Lake Worth and Bridgeport	41,112		58,277	99,389		128,622	69,389	198,011	297,400
3. Clear fork	18,294		26,805	45,099		46,513	124,633	171,146	216,245
4. Denton Creek	37,785		44,460	82,245		114,133	139,017	253,150	335,395
5. Hickory Creek	11,790			11,790		29,910	33,192	63,102	74,892
6. Elm fork above Lake Dallas	62,712		11,965	74,677		190,073	224,591	414,664	489,341
7. Little Elm Creek	20,004			20,004		46,300	44,404	90,704	110,708
8. East fork	115,872			115,872		292,598	294,792	587,390	703,262
9. White Rock above dam	11,346			11,346		24,617	25,018	49,635	60,981
10. Mountain Creek above dam	21,261			21,261		53,869	47,829	101,698	122,959
11. Cedar Creek	68,025	$1,446		69,471	$2,792	208,041	250,763	458,804	531,067
12. Chambers-Richland Creek	156,939			156,939		409,022	439,475	848,497	1,005,436
13. Fort Worth-Dallas area	63,306			63,306		173,408	143,791	317,199	380,505
14. Trinity-Red Oak area	78,429	478		78,907	924	192,748	228,698	421,446	501,277
15. Tehuacana-Catfish Creeks	69,948	2,459		72,407	4,749	213,151	197,072	410,223	487,379
All areas	815,160	4,383	146,167	965,710	8,465	2,192,666	2,310,723	4,503,389	5,477,564

ANNUAL EQUIVALENT OF BENEFITS FROM PROGRAM

Flood-problem area	Flood-control benefits				Conservation benefits				Average benefits per dollars of costs
	Reduction in recurrent flood damages [7]	Increase in net farm income resulting from changes in use of flood plain [7]	Reduction in reservoir sedimentation [8]	Total	Increase in gross farm income and decrease in farm expenses on private farms [6]	Increase in total income from public land in purchase area [2]	Total	All benefits	
1. West fork above Lake Bridgeport	$6,045	$6,065	$29	$12,139	$329,641	$7,260	$336,901	$349,040	$2.17
2. West fork between Lake Worth and Bridgeport	36,774	[9] 27,613	5,774	70,161	338,825	90,815	429,640	499,801	1.68
3. Clear fork	12,930	7,778	876	21,584	283,624	41,758	325,382	346,966	1.60
4. Denton Creek	20,250	0	0	20,250	684,631	69,306	753,937	774,187	2.31
5. Hickory Creek	24,787	428	0	25,215	243,706		243,706	268,921	3.59
6. Elm Fork above Lake Dallas	80,645	[10] 4,692	14,863	100,200	1,341,466	18,640	1,360,106	1,460,306	2.98
7. Little Elm Creek	12,472	0	0	12,472	359,913		359,913	372,385	3.36
8. East fork	55,767	88,173	185	144,125	2,057,513		2,057,513	2,201,638	3.13
9. White Rock above dam	2,428	501	31,146	34,075	191,694		191,694	225,769	3.70
10. Mountain Creek above dam	27,495	2,792	23,127	53,414	399,581		399,581	452,995	3.68
11. Cedar Creek	38,067	[10] 281,739	1,869	321,675	1,361,840		1,361,840	1,683,515	3.17
12. Chambers-Richland Creek	230,660	[9] 263,202	1,040	494,902	3,119,664		3,119,664	3,614,566	3.60
13. Fort Worth-Dallas area	8,308	11,089	2,981	22,378	1,126,593		1,126,593	1,148,971	3.02
14. Trinity-Red Oak area	16,642	11,051	370	28,063	1,378,532		1,378,532	1,406,595	2.81
15. Tehuacana-Catfish Creeks	24,951	[10] 51,911	158	77,020	917,366		917,366	994,386	2.04
All areas	598,221	757,034	82,418	1,437,673	14,134,589	227,779	14,362,368	15,800,041	2.88

[1] Interest on installation and supervision at 3 percent.
[2] Interest on installation cost at 3 percent plus average annual maintenance cost.
[3] See tables H–4 and H–5, appendix H, for method of securing annual equivalent costs and benefits.
[4] Interest on installation cost at 4 percent plus average annual maintenance cost.
[5] Interest on installation cost at 5 percent, plus annual farmer maintenance cost of remedial measures installed on private farm land and leased public land. (See tables F–18 and H–5.)
[6] See table F–18. Explanation of method used in securing these estimates is given in appendix E.
[7] See table F–15.
[8] See table F–16.
[9] Discounted for 5-year lag in flood-plain development.
[10] Discounted for 10-year lag in flood-plain development.

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